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Draft Supplement to the Final Environmental Statement

related to the decommissioning of the
Rare Earths Facility, West Chicago, Illinois

Docket No. 40-2061

Kerr-McGee Chemical Corporation

**U.S. Nuclear Regulatory
Commission**

Office of Nuclear Material Safety and Safeguards

June 1967



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II

ABSTRACT

This Draft Supplemental Environmental Statement (DSES) assesses the impacts of permanent disposal of wastes located at the Kerr-McGee Rare Earths Facility in West Chicago, Illinois. The assessments presented in the DSES augment and update those described in the Final Environmental Statement (FES) that was issued by the U.S. Nuclear Regulatory Commission (NRC) in May 1983. In this DSES, additional alternative sites are analyzed, the analysis is more detailed, and the NRC expressly considers the suitability of these sites for permanent waste disposal. The analysis describes the Proposed Action, which is permanent disposal of the wastes in an above-grade disposal cell at the West Chicago site, and four alternatives for permanent disposal at other sites in Illinois. The four alternatives are: Alternative A, disposal at an active surface coal mine in a deep-trench disposal cell; Alternative B, disposal in a reclaimed surface coal mine in a deep-trench disposal cell; Alternative C, disposal in an underground coal mine in a worked-out panel; and Alternative D, disposal on a farmland site in a partially above-grade disposal cell. The environmental issues considered in the impact assessment are topography, air quality, socioeconomic, land resources, archeology, mineral resources, water resources, ecology, and radiation exposure. A cost-benefit analysis of the Proposed Action and its alternatives is also presented. Based on the information and analysis given within this DSES, the NRC concluded that the Proposed Action is the preferred course of action.

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PREFACE

This Draft Supplemental Environmental Statement (DSES) has been prepared in response to the Atomic Safety and Licensing Board's ruling that the U.S. Nuclear Regulatory Commission (NRC) staff must supplement the Final Environmental Statement (FES) in order to evaluate the impacts of permanent disposal of the Kerr-McGee Rare Earths Facility wastes located at West Chicago, Illinois. Kerr-McGee Chemical Corporation (West Chicago Rare Earths Facility), LBP-85-3, 21 NRC 244, at 256 (1985). The NRC, with the technical assistance of Argonne National Laboratory, prepared this DSES pursuant to NRC regulations (10 CFR Part 51), which implement requirements of the National Environmental Policy Act (NEPA) of 1969 (Public Law 91-190).

This environmental review deals with the impacts of permanent disposal of the Rare Earths Facility wastes. The assessments presented in this DSES augment and update those described in the FES that was issued in May 1983. The NRC has undertaken in this draft supplement an analysis of alternative sites beyond those considered in the FES and has expressly considered the suitability of the sites for permanent waste disposal.

This DSES is limited in scope to the materials on the Kerr-McGee site itself and materials authorized to be stored on the site but not yet placed there. Nearby areas -- Reed-Keppler Park and areas along and in Kress Creek -- are known to contain contaminated materials; however, cleanup of these sites is not addressed in the DSES. This DSES summarizes the analyses and evaluations made and identifies a preferred course of action for the decommissioning of the West Chicago site that will serve as a basis for the licensing decisions by NRC.

1. SUMMARY

1.1 PROJECT BACKGROUND

The Kerr-McGee Chemical Corporation's (Kerr-McGee) Rare Earths Facility is located in the city of West Chicago in DuPage County, Illinois. The facility occupies a total area of about 17 ha (43 acres) and has been subdivided by Kerr-McGee into three areas -- the Factory Site, the Intermediate Site, and the Disposal Site.

The facility began operations in 1931 and closed in 1973. During the operational period of the plant, various chemical processes were used to produce thorium and rare earth compounds. The processing activities produced waste materials such as sands, sludges, and sediments. These materials, which accumulated over the years, were stored initially on the Factory Site and subsequently on the Disposal Site.

In 1979, Kerr-McGee submitted a stabilization plan to the U.S. Nuclear Regulatory Commission (NRC) for decommissioning the inactive West Chicago site and stabilizing the accumulated wastes and tailings. The plan was later modified by Kerr-McGee and used by NRC in its preparation of a Final Environmental Statement (FES) that was issued in May 1983.* In the FES, NRC concluded that, rather than permanent disposal, on-site storage in an improved disposal cell should be approved and a decision on permanent disposal deferred until several years of monitoring data had been accumulated.

The NRC's conclusion was based, in part, on the fact that the U.S. Environmental Protection Agency (EPA) had not yet adopted regulations setting forth standards for permanent disposal of mill tailings pursuant to the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 and the NRC's criteria for mill tailings disposal (10 CFR Part 40, Appendix A) had been in part temporarily suspended by Congressional action.

In Kerr-McGee Chemical Corporation (West Chicago Rare Earths Facility), LBP-84-42, 20 NRC 1296 (1984), the Atomic Safety and Licensing Board presiding over a hearing on Kerr-McGee's license amendment application ruled that the basis on which the staff had refused to consider Kerr-McGee's proposal for permanent on-site disposal had been overtaken by the EPA's promulgation of final rules governing mill tailings disposal. Id., 20 NRC at 1311. Thus, the Board concluded that the staff's treatment of Kerr-McGee's request was a

*The complete reference citation for the FES is provided in the reference list at the end of this chapter. Hereafter in this document, the reference will be cited only as FES.

segmentation impermissible under the decisions construing the National Environmental Policy Act (NEPA) of 1969 and that permanent disposal must be considered by the staff. Id., 20 NRC at 1311-1317. In a subsequent decision, the Board further concluded that the failure to have assessed permanent disposal of the Rare Earths Facility wastes in the FES dictated that a supplemental impact statement be prepared and circulated for comment, or that the FES be recirculated with an amendment addressing permanent disposal. Kerr-McGee Chemical Corporation (West Chicago Rare Earths Facility), LBP-85-3, 21 NRC 244, at 256 (1985).

This supplement to the FES has been prepared in accordance with the Board's decisions. Although the Board did not find that the alternative site analysis in the FES was inadequate (Id.), the NRC has undertaken an expanded independent analysis of alternative sites in this supplement and has expressly considered the suitability of alternative sites for permanent waste disposal.

In addition, the estimated waste volume at the West Chicago site has been significantly increased since 1983. Kerr-McGee has performed extensive testing on the site, resulting in a better estimate of the amount of waste there. Kerr-McGee has also been authorized to store contaminated materials from the residential cleanup program and the sewage treatment plant at the site. The new waste volume has been used in the analysis presented in this supplement. See LBP-84-42, supra, 20 NRC at 1318.

1.2 IDENTIFICATION OF ALTERNATIVES

Permanent disposal of the waste materials at the West Chicago site, described in the most recent engineering design prepared by Kerr-McGee (1986), is identified as the Proposed Action.

For Alternative A, the site chosen for analysis is the Midland Coal Company's Rapatee Mine in northeastern Fulton County, Illinois. A final-cut pit would be used for the construction of a deep-trench disposal cell.

For Alternative B, a reclaimed surface coal mine located in western Peoria County, Illinois, and formerly operated by Midland Coal Company was selected for analysis. A final-cut pit would also be used at this site for the construction of a deep-trench disposal cell.

For Alternative C, the Ziegler Coal Company's Murdock underground coal mine in eastern Douglas County, Illinois, was selected. Under this alternative, the wastes would be transported down into the underground mine, using mostly in-place equipment, and placed into a worked-out panel as tightly as possible. After a mine panel was completely filled, the bulkhead seals would be used to wall off the encapsulated wastes.

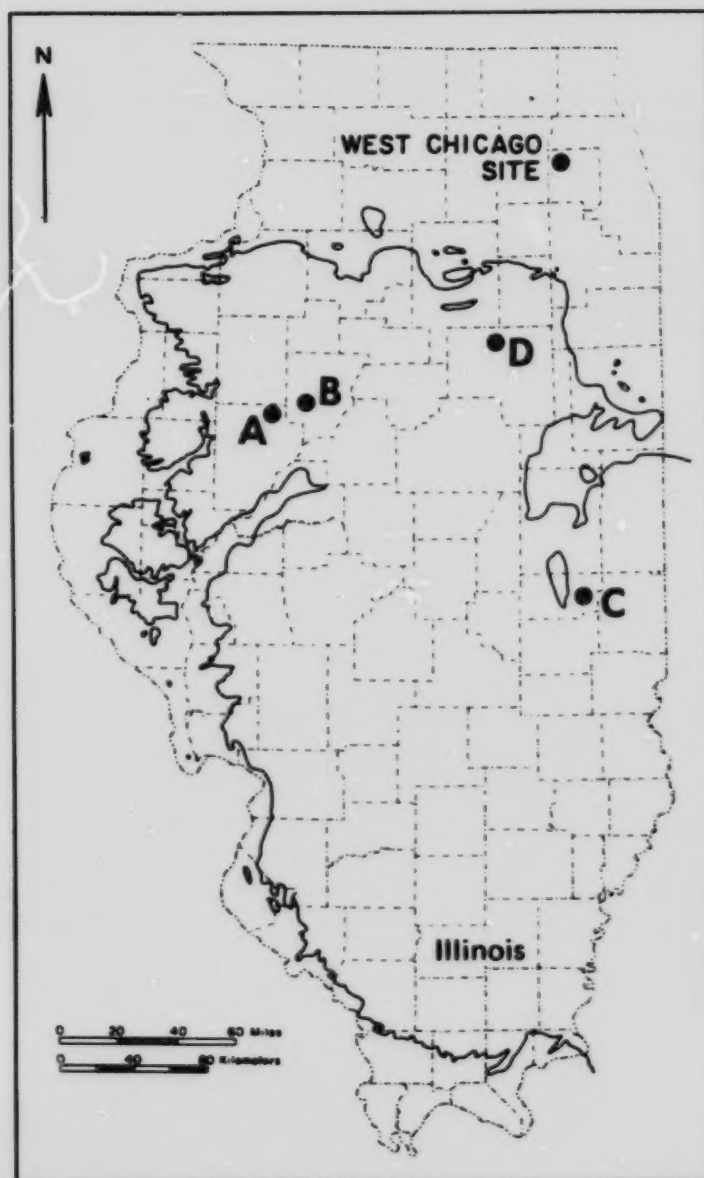
For Alternative D, a large farmland area was evaluated, and a suitable site close to West Chicago was chosen for minimizing transportation costs and potential risks from transportation accidents. The selected site is located in north-central Livingston County, Illinois, and has geological and hydrological conditions that are well suited for a waste-disposal site. A partially above-grade cell could be used for this site.

Figure 1.1 shows the locations of the five alternative sites. The clay/shale quarry sites considered in the FES as potential alternative disposal sites have been determined in this study to be inappropriate for receiving Kerr-McGee wastes, based on the most recently available site information. The process by which the alternative sites were chosen for this analysis is described in Appendix A. None of the landowners and/or coal mine operators of the sites considered for Alternatives A through D have reviewed this document or have been consulted as to the availability of their sites. Therefore, the inclusion of these sites in this supplement does not imply that they would necessarily be available for the disposal of the Kerr-McGee wastes.

The use of currently licensed low-level-waste (LLW) disposal sites (i.e., Beatty, Nevada; Barnwell, South Carolina; Hanford, Washington) or future state compact LLW disposal facilities has been considered, but was excluded from further evaluation for the following reasons.

The Low-Level Radioactive Waste Policy Amendments Act (LLRWPA) of 1985 (42 U.S.C. 2021b et seq.) defines low-level radioactive waste as radioactive waste that is "not high-level radioactive waste, spent nuclear fuel, or byproduct material (as defined in Section 11e.(2) of the Atomic Energy Act of 1954 (42 U.S.C. 2014(e)(2))." Section 11e.(2) defines by-product material as "the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content." Based upon analysis reflected in the FES (Appendix H, pp. H-2 to H-5), the NRC staff has concluded that the wastes that were generated at the Rare Earths Facility and stored on-site should be considered to be by-product material.* The LLRWPA returned to each state the responsibility to dispose of low-level radioactive wastes generated in that state. The legislation did not enlarge the authority of the states over radioactive wastes other than low-level. Thus, the LLRWPA does not change existing law regarding wastes such as those at the West Chicago site.

*Radioactively contaminated material from residential areas in West Chicago and from the Sewage Treatment Plant are classified by NRC as source material and have become the regulatory responsibility of the state of Illinois pursuant to an agreement executed between NRC and the state under Section 274b of the Atomic Energy Act of 1954 (42 U.S.C. 2021b) (U.S. Nucl. Reg. Comm. 1987a, 1987b).



- West Chicago Site - Proposed Action
A - Rapatee Active Surface Coal Mine
B - Elm Reclaimed Surface Coal Mine
C - Murdock Underground Coal Mine
D - Farmland Site
~ - Coal basin boundary

Figure 1.1. Locations of the Potential Disposal Sites.

Although the LLRWPA does not require the disposal sites established under that statute to accept 11e.(2) by-product material for disposal, no provision of the statute explicitly prohibits states from accepting these materials. However, even though the LLRWPA does not explicitly prohibit the regional disposal facilities located at Barnwell, South Carolina; Richland, Washington; and Beatty, Nevada; from accepting by-product material for disposal at these facilities, the Act sets certain limitations on the availability of Barnwell, Richland, and Beatty. Under the Act as amended, the state of South Carolina may limit the volume of low-level radioactive waste accepted for disposal at Barnwell to a total of 238,000 m³ (311,000 yd³) during the 7-year period beginning January 1, 1986, and ending December 31, 1992; the state of Washington may limit the amount of such waste for disposal at Richland to 278,000 m³ (363,000 yd³) during that same period, and the state of Nevada may limit the amount of such waste for disposal at Beatty to 39,700 m³ (51,900 yd³) for that same period. Thus, the three states in which the existing sites are located may limit the total amount of low-level wastes to be disposed of at these sites during the 7 years ending December 31, 1992, to 555,000 m³ (726,000 yd³).

The three existing disposal facilities are required to accept as much as 337,000 m³ (441,000 yd³) of low-level radioactive waste generated by commercial nuclear power reactors during the 7-year interim access period. Thus the total capacity available for the Kerr-McGee wastes at the three existing waste disposal facilities is 218,000 m³ (285,000 yd³). This is less than the total volume, 282,000 m³ (369,000 yd³), of waste materials at the West Chicago site.

Because the total available capacity of the three interim sites is less than that required to dispose of the Kerr-McGee wastes, disposal at these sites need not be evaluated under NEPA as an alternative to Kerr-McGee's proposed plan to dispose of the wastes on-site.

Disposal at one of the interstate compact sites need not be considered as an alternative to on-site disposal at West Chicago because these facilities will not be available in the time frame anticipated for disposal of the Kerr-McGee wastes and because no compact facility would be required to accept these wastes. The Central Midwest Compact, of which Illinois is a member, would not be obligated to accept the Kerr-McGee wastes, even if the Central Midwest Compact facility were ready to accept wastes for disposal in the required time frame. The Central Midwest Compact defines low-level radioactive waste as excluding among other things "by-product material as defined in Section 11e.(2) of the Atomic Energy Act of 1954." The NRC has also considered the possibility of co-location of the Rare Earths Facility wastes in the vicinity of the Central Midwest Compact low-level waste burial site.

However, because such a site has not yet been selected, the staff did not analyze this alternative further.

1.3 CHARACTERIZATION OF THE AFFECTED ENVIRONMENT

The selected alternative sites are all located in the state of Illinois and are within a distance of about 290 km (180 mi) from the West Chicago site (Figure 1.1). The environmental characteristics of these sites are generally very similar. In order to assess the potential environmental impacts associated with disposal of the Kerr-McGee wastes at the West Chicago site or at one of the alternative sites, the baseline data were analyzed to determine each site's physical, biological, and sociological characteristics.

1.3.1 West Chicago Site

The West Chicago site is a 17-ha (43-acre) parcel located in a residential-industrial area on the southwest side of the city of West Chicago in DuPage County, Illinois. The climate of the site area is typically continental with cold winters, warm summers, and frequent short-period fluctuations in temperature, humidity, cloudiness, and wind direction. The monthly average temperature in the area ranges from a maximum of 28.4°C (83.1°F) in the summer to a minimum of -9.6°C (14.7°F) in the winter. The average annual precipitation in the West Chicago area is about 80.6 cm (31.7 in.). Winds come mainly from the west.

The topography of the West Chicago site has been extensively modified over the years by earth-moving and landfilling activities. The land surface elevation at the site generally ranges from approximately 232 m (761 ft) above mean sea level (MSL) at the north end to 223 m (732 ft) MSL at the south end, with a southwesterly slope toward Kress Creek.

Kress Creek and the West Branch DuPage River are the two major surface streams in the area. Surface drainage from the site area is toward these two southward-flowing streams. Analysis of sediment samples indicates the presence of thorium contamination along the banks of both the creek and the river. There is no evidence of nonradiological contamination of the streams from the West Chicago site. Groundwater at the West Chicago site occurs in a water-table system. The glacial drift and Silurian dolomite aquifers are the most important shallow aquifers in the site area. Under the Disposal Site, groundwater contains elevated levels of several nonradiological substances. Concentrations of radiological elements are generally below regulatory limits for groundwater quality of both the EPA and the state of Illinois.

Terrestrial habitats at the West Chicago site consist of disturbed, open areas characteristically associated with developed suburban/urban locations.

These essentially open lands are in the early stages of succession and are comprised of a mixture of lawn-like to old-field habitat, with sparse intermingling of trees and shrubs. Associated fauna include an assemblage of small- to medium-sized mammals, birds, reptiles, and amphibians that are adapted to suburban/urban locations. The habitats of these species include lawns, old fields, roadsides, fencerows, waste grounds, and so forth. On-site aquatic habitats consist of several variously sized ponds. Fish were not observed in the ponds; but waterfowl, reptiles, and amphibians visit these ponds. Also, an assortment of macrophytes, algae, and invertebrates occur in the ponds. Site drainage flows into Kress Creek, which is polluted from industrial, municipal, and agricultural wastes. Pollution-tolerant fish and macroinvertebrates inhabit the creek.

1.3.2 Alternative Sites

The alternative sites considered in this study include an active surface coal mine at Rapatee, a reclaimed surface coal mine in western Peoria County, an underground coal mine in eastern Douglas County, and a farmland site in north-central Livingston County (Figure 1.1). All of these sites are located in the northern half of the state of Illinois. The alternative site characteristics are summarized in Table 1.1.

Similar to the West Chicago site, the alternative sites have a typical continental climate. The monthly average temperature in these areas ranges from a maximum of about 31.1°C (88.1°F) in July to a minimum of -9.2°C (15.5°F) in January. The average annual precipitation in the alternative site areas ranges from about 87 cm (34 in.) to 98 cm (39 in.). The Murdock underground coal mine is located farther south than the other alternative sites and therefore has the warmest temperatures and least amount of precipitation among the alternative sites.

Topographically, the alternative sites are generally located on relatively flat upland. The surface elevation ranges from about 200 to 235 m (656 to 771 ft) MSL with moderate relief. The sites are all well drained by the nearby creeks. The water quality of the streams is generally good, with occasional high concentrations of ions such as sulfate, sodium, nitrate, and potassium due to fertilizer contributions to runoff.

Groundwater in the alternative site areas occurs in the unconsolidated glacial deposits and in the underlying bedrocks. The quality of the water is generally good, with occasional high concentrations of iron and total dissolved solids. Groundwater is used for public and industrial supply and for rural domestic and livestock uses. Most of the public and industrial groundwater supplies were pumped from the glacial drift and deep bedrock aquifers.

Table 1.1. Summary of Potential Disposal Site Characteristics

Alternative	Site	County	Transportation Distance from West Chicago (km)	Nearest Town (population)	Nearest Streams	Range of Surface Elevation (m MSL)
Proposed Action, On-site disposal	West Chicago	DuPage	0	West Chicago ^a (12,550)	Kress Creek	223-232
A, Active Surface Coal Mine	Rapatee Mine	Fulton	290	Rapatee ^b (<550)	Littlers Creek, Coal Creek, Swegle Creek	205-220
B, Reclaimed Surface Coal Mine	Elm Mine	Peoria	274	Elmwood ^a (2,115)	West Fork of Kickapoo Creek	200-235
C, Underground Coal Mine	Murdock	Douglas	265	Murdock ^b (14)	Brushy Fork	210-220
D, Farmland		Livingston	129	Blackstone ^b (75)	Small creeks	220-227

^a Based on 1980 census of population (U.S. Bur. Census 1982).

^b Data from Rand McNally (1986).

Habitats and biotic composition at the alternative sites are generally similar to those at the West Chicago site. The sites are in early stages of secondary succession associated with past or current disturbances from mining or agricultural activities. However, overall biotic diversity is potentially greater at the alternative sites because of the absence of urban encroachment and the more rolling terrain (particularly at the surface mine sites). However, some areas of the alternative sites could be devoid of or contain only sparse biotic communities. Such areas would most likely exist in the disturbed portions of the active surface coal mine, by the entrance to the underground coal mine, in areas of the reclaimed surface coal mine where revegetation may not have been successful, or in areas of the farmland that are in agricultural production. Aquatic habitats at the alternative sites could range from none to any or all of the following: ponds, strip mine lakes, wetlands, intermittent streams, and permanent streams.

1.4 EVALUATION OF ENVIRONMENTAL IMPACTS

The potential impacts from disposal of the Kerr-McGee wastes at each of the potential disposal sites are summarized and compared in Table 1.2 and discussed in detail in Chapter 5. The environmental issues considered in the impact assessment include topography, air quality, socioeconomics, land resources, archeology, mineral resources, water resources, ecology, and radiation exposure. The results of the impact assessment are briefly described as follows.

At the West Chicago site, the most significant nonradiological impacts would be those associated with excavation and transportation of the contaminated materials and fill materials into and out of the site. These impacts would be similar for all alternatives. Transportation problems with on-site disposal would occur in the form of periodic road closings, traffic congestion, dust, noise, and damage to roads. These problems would be more severe if the wastes were transported off-site for disposal because the number of trucks needed to transport the wastes would be greater. However, all transportation problems would be temporary and mitigable. Other nonradiological impacts would include construction noise and dust, temporary inconvenience to residents at certain times, small increases in gaseous pollutants and particulate emissions, and some localized siltation of Kress Creek. These problems could be managed, and appropriate measures -- such as dust suppression, vehicle mufflers, work scheduling, wastewater treatment, and erosion control -- could be taken to mitigate their severity. Because of the need for fill materials, a permanent off-site borrow pit would be created.

Table 1.2. Comparison of Potential Impacts at Each Alternative Site

Environmental Factor	Proposed Action (West Chicago Site)	Alternative A (Rapatee Active Surface Coal Mine)	Alternative B (Elm Reclaimed Surface Coal Mine)	Alternative C (Murdock Under- ground Coal Mine)	Alternative D (Livingston County Farmland)
<u>Topography</u>					
Short-term ^a	Temporary storage piles of wastes and borrow materials would be created.	Similar to Proposed Action.	Similar to Proposed Action.	Similar to Proposed Action.	Similar to Proposed Action.
Long-term ^a	Above-grade disposal cell would cover 12 ha and be about 12 m above surrounding topography; permanent off-site borrow pit and on-site retention basin would be created.	West Chicago site would be graded smooth and off-site borrow pit would be created.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A; 7-m high disposal mound would be created at farmland site.
<u>Air Quality (Total) -- All standards would be met at all sites.</u>					
Short-term:					
TSP ($\mu\text{g}/\text{m}^3$)	Annual	45.4	38.9	34.6	45.4
	24-hour	115.2	118.6	104.6	130.2
SO ₂ ($\mu\text{g}/\text{m}^3$)	Annual	17.8	27.6	18.5	26.4
	24-hour	81.0	164.4	163.9	115.0
	3-hour	222.0	300.4	301.7	231.4
NO ₂ ($\mu\text{g}/\text{m}^3$)	Annual	37.0	-	-	-
CO (mg/m^3)	8-hour	6.3	8.4	9.2	6.3
	1-hour	13.8	19.1	14.5	13.8
Pb ($\mu\text{g}/\text{m}^3$)	Quarterly	0.25	0.32	-	0.20
Long-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
<u>Socioeconomics</u>					
Demography:					
Short-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
Long-term	Possible human intrusion.	Possible human intrusion, but less than Proposed Action.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A.
Transportation:					
Short-term	Traffic congestion, dust, noise, and road damage at West Chicago.	Traffic congestion, dust, noise, and road damage at West Chicago and the disposal site.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A.
Long-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.

Table 1.2. Continued

Environmental Factor	Proposed Action (West Chicago Site)	Alternative A (Rapatee Active Surface Coal Mine)	Alternative B (Elm Reclaimed Surface Coal Mine)	Alternative C (Murdock Under- ground Coal Mine)	Alternative D (Livingston County Farmland)
<u>Property Values:</u>					
Short-term	Possible adverse impacts.	Minimal impact at site.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A.
Long-term	Possible positive or adverse impacts.	No impact at site, increased property values at West Chicago.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A.
<u>Taxes:</u>					
Short-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
Long-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
<u>Land Use:</u>					
Short-term	Not relevant.	Not relevant.	Not relevant.	Not relevant.	Not relevant.
Long-term	Permanent loss of land for other use.	Permanent loss of land for other use.	Similar to Alt. A.	Similar to Alt. A.	About 19 ha of farmland eliminated.
<u>Archeological</u>					
Short-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
Long-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
<u>Mineral Resources</u>					
Short-term	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
Long-term	On-site sand and gravel deposits no longer mineable.	Some small coal reserves removed from future production.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A.
<u>Erosion</u>					
Short-term	Minimal impact if maintained.	Minimal impact.	Minimal impact.	Minimal impact.	Minimal impact.
Long-term	Minimal impact if converted to mature forest or grasses.	Similar to Proposed Action.	Similar to Proposed Action. Spoil hills removed.	No impact.	Similar to Proposed Action.
<u>Surface Water -- National Pollutant Discharge Elimination System requirements would be satisfied.</u>					
Short-term	Temporary increase of sediment and contaminant concentrations in nearby creeks.	Similar to Proposed Action at West Chicago site and at disposal site.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A.
Long-term	Minimal impact.	Minimal impact.	Minimal impact. Spoil hills removed.	Minimal impact.	Minimal impact.

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Table 1.2. Continued

Environmental Factor	Proposed Action (West Chicago Site)	Alternative A (Rapatse Active Surface Coal Mine)	Alternative B (Elm Reclaimed Surface Coal Mine)	Alternative C (Murdock Under- ground Coal Mine)	Alternative D (Livingston County Farmland)
<u>Groundwater</u> -- Some groundwater standards would be exceeded.					
Short-term	Reduced leaching of contaminants into groundwater.	Similar to Proposed Action at West Chicago site; Minimal impact at disposal site.	Similar to Alt. A.	Similar to Alt. A.	Similar to Alt. A.
Long-term	Minimal impact.	Groundwater standards exceeded by arsenic, cadmium, copper, lead, mercury, and cyanide.	Groundwater standards exceeded by cadmium, copper, lead, mercury, and cyanide.	Groundwater standard exceeded by cyanide.	Groundwater standards exceeded by arsenic, cadmium, copper, lead, and cyanide.
<u>Ecology</u>					
<u>Terrestrial:</u>					
Short-term	Temporary disruption and loss of habitat and associated vegetation; concurrent loss and/or displacement of wildlife.	Similar to Proposed Action (for the area already reclaimed); --or-- No impact except delayed restoration (for recently mined area).	Similar to Proposed Action.	No impact if disturbed areas outside of mine used; --or-- Similar to, but less extensive than, West Chicago if areas required outside of mine have established biotic communities.	Similar to Proposed Action.
Long-term	Habitat and biota would be reestablished; recurring impacts to biota if active site maintenance occurs. Potential for biointrusion into wastes.	Similar to Proposed Action except unlikely potential for biointrusion into wastes.	Similar to Alt. A.	No potential for biointrusion into wastes.	Similar to Proposed Action.
<u>Aquatic:</u>					
Short-term	No to low potential for increased suspended solids to receiving streams.	No to low potential for increased suspended solids to receiving streams, strip mine lakes, area ponds, or wetlands.	Loss of strip mine lake.	No to low potential for increased suspended solids to receiving streams, area ponds, or wetlands.	Similar to Alt. C.
Long-term	Loss of on-site ponds.	No to low potential for loss of strip mine lakes, on-site ponds, wetlands, or tributary streams.	Loss of one strip mine lake; otherwise similar to Alt. A.	Minimal impact.	No to low potential for loss of on-site ponds, wetlands, or tributary streams.

Table 1.2. Continued

Environmental Factor	Proposed Action (West Chicago Site)	Alternative A (Rapatow Active Surface Coal Mine)	Alternative B (Ela Reclaimed Surface Coal Mine)	Alternative C (Murdock Under- ground Coal Mine)	Alternative D (Livingston County Farmland)
<u>Radiological</u> -- Current guidelines would not be exceeded.					
Estimated Dose to General Public (person-rem):					
Short-term (effective dose)	36	1,300	1,300	1,200	890
Long-term (bronchial epithelium dose)	1,800	Negligible	Negligible	Negligible	270
Estimated Health Effects to General Public:					
Short-term	0.0061	0.22	0.22	0.20	0.15
Long-term	0.019	Negligible	Negligible	Negligible	0.0028
Estimated Dose to Workers (person-rem):					
Short-term	610	630	620	560	860
Estimated Health Effects to Workers:					
Short-term	0.10	0.11	0.11	0.097	0.15
<u>Project Requirements</u>					
Work force (person-years):					
Short-term					
Total	104	224	223	201	220
Range	60-140	130-310	130-310	120-280	130-310
Long-term					
Annual (person-years)					
First 5 years	2	1	1	0.5	2
Next 5 years	1	0.5	0.5	0.25	1
Next 990 years	0.3	0.25	0.25	0.12	0.5
Total	310	260	260	130	310
Range	150-870	78-440	78-440	34-220	150-870
Cost (\$M):					
Short-term	16	37	37	36	35
Range	9.6-22	34-80	34-80	34-78	33-77
Long-term	41	20	20	10	41

* Short-term, during action period (about 7 years); long-term, for a period of 1,000 years.

Loss of habitat and associated biota would occur at the West Chicago site regardless of which site is designated for waste disposal. This would include permanent loss of the on-site ponds and elimination of habitats for pest species such as rats, pigeons, and mosquitoes. In addition, remedial actions would remove sources of potential chemical and radioactive contamination for wildlife. Terrestrial habitat would be restored at the site following waste removal/disposal activities.

The potential radiological impacts would be those connected with movement of the radioactively contaminated materials from their current locations to the selected disposal site location. Such movement would result in airborne emissions of radioactively contaminated particulates and gases. These impacts would be somewhat larger for on-site disposal (Proposed Action) than for the off-site disposal alternatives (A through D) because of the population distribution. These materials could be transported off-site by wind, resulting in potential radiation doses to persons in the vicinity of the site. The cumulative dose to the general public from waste handling, not including transportation activities, is estimated to be 36 person-rem for on-site disposal and 26 to 27 person-rem for Alternatives A through D. The hypothetical maximally exposed individual, located 0.23 km (0.14 mi) northeast of the center of the West Chicago disposal area, would receive an estimated dose of 40 mrem for on-site disposal and 20 mrem for Alternatives A through D. These doses are not expected to produce any adverse health effects.

The radiological impacts would be dramatically reduced following completion of remedial activities. The potential for leaching of contaminants into groundwater would be significantly reduced. The only release of any significance would be emissions of radon-222 gas to the atmosphere. The annual dose to the general public in the vicinity of the West Chicago site is estimated to be 1.8 person-rem/yr to the bronchial epithelium following completion of the Proposed Action. The maximally exposed individual would receive a bronchial epithelium dose of 0.0068 mrem/yr. These doses represent insignificant increments to the radiation doses that would be received from background sources of radioactivity and are not expected to produce any adverse health effects. There would be no long-term radiological impacts in the West Chicago area following completion of Alternatives A through D because the wastes would be removed from the site.

The potential environmental impacts for Alternatives A through D would be quite similar. The nonradiological impacts at the disposal sites would include temporary road closings, traffic congestion, dust, small increases in gaseous pollutants and particulate emissions, and runoff of eroded materials into local streams. These impacts are manageable and are expected to be less severe than at the West Chicago site. A permanent borrow pit would be created

because of the need for fill material at the West Chicago site. In addition, some small coal reserves or areas of farmland would not be available for future production.

Impacts to habitats and biota at the alternative sites (except the underground coal mine site) would be similar to those at the West Chicago site. Site restoration would also be similar. Somewhat larger areas that might be impacted at the alternative sites would be compensated for by the greater expanse of habitat into which fauna could be displaced and which could serve as a source of recolonizing species. Fewer impacts are expected to occur at the active surface mine site (if a recently mined pit is used) or at the farmland site (if an area of active crop production is used) than at the West Chicago site. Some ponds, wetlands, and small streams (and associated biota) could be impacted if located at one of the alternative sites. Minor siltation to streams receiving site drainage could also occur during the period of waste-disposal activities. Few impacts would occur at the underground coal mine site; impacts would occur only if the area near the mine entrance had developed biotic communities that would be temporarily destroyed for staging areas, waste handling, and so forth. The potential for bio-intrusion into the wastes would exist primarily at the farmland site.

The radiological impacts from implementing any of the off-site disposal alternatives (A through D) would be significantly greater than for on-site disposal (Proposed Action), primarily because of the population dose associated with transportation of the Kerr-McGee wastes from West Chicago to an alternative disposal site. The cumulative doses to the general public resulting from transportation are estimated to be: Alternative A or B, 1,300 person-rem; Alternative C, 1,200 person-rem; and Alternative D, 860 person-rem. The estimated dose to members of the general public in the vicinity of the alternative disposal sites is less than 1 person-rem because of the relatively remote locations of these sites.

The radiological impacts in the long-term period would be smaller for the off-site alternatives than for on-site disposal (Proposed Action) because of the more remote locations of the off-site alternatives. There would be minimal impacts on groundwater from radionuclide contamination for the off-site alternatives. The dose to the general public during the long-term period would be primarily associated with radon-222 gas emissions. The average annual bronchial epithelium dose to the general public is estimated to be 1.8 person-rem/yr for the Proposed Action and 0.27 person-rem/yr for Alternative D. Only a negligible amount of radon-222 gas would be released in Alternative C because of the deep burial depth (80-100 m) or for Alternatives A and B because of the attenuation effect of the thick clay cover. The bronchial epithelium dose to the maximally exposed individual would be less

than 1 mrem/yr for the Proposed Action and all alternatives. These doses represent insignificant increments to the radiation dose received from background sources of radioactivity and are not expected to result in any adverse health impacts.

1.5 MAINTENANCE AND MONITORING

After all of the cleanup work was completed, Kerr-McGee would continue to monitor the final disposal site for 25 years to ensure that the remedial action program continued to comply with EPA standards (40 CFR Part 192). This could include measurements of parameters such as air and water contaminant levels. The required monitoring and maintenance would be specified in the license issued by NRC. The EPA standards (40 CFR Part 192) would have to be met before the remedial action was considered officially completed. The proposed monitoring programs that would be implemented prior to, during, and after the remedial action are discussed in Chapter 7 of the FES and in this Supplemental Environmental Statement. For long-term monitoring, any federal or state agency charged with custody of the disposal site would be responsible for such activity.

1.6 COST-BENEFIT ANALYSIS

A cost-benefit analysis of the Proposed Action and its alternatives has been carried out; the details and results are given in Chapter 8. Two different rankings of environmental and monetary factors were considered. Both rankings show that the Proposed Action is preferable to the alternatives considered. The ordering of the alternatives depends on the weighting or ranking of the monetary and environmental factors. If consideration is restricted to monetary, air quality, groundwater, and radiological factors (as the most important) and these are given equal weight (and factors for the action period and long-term period are given equal weight), then Alternative C is next in order of preference, followed by Alternative D; Alternative A is the least preferable and Alternative B is only slightly more preferable than Alternative A. If all monetary and environmental factors are assigned equal weight (and factors for the action period and the long-term period are given equal weight), then Alternative B is next in order of preference, followed by Alternative C; Alternative A is slightly less preferable than Alternative C and Alternative D is the least preferable.

1.7 CONCLUSION

In comparing alternative disposal sites to the proposed West Chicago disposal site, the staff applied the standard that the Proposed Action can only be denied if an alternative site(s) is identified that is obviously

superior to the West Chicago site. See Public Service Co. of New Hampshire (Seabrook Station, Units 1 & 2), CLI-77-8, 5 NRC 503, 526-30 (1977); Rochester Gas and Electric Corp. (Sterling Power Project, Nuclear Unit No. 1), ALAB-502, 8 NRC 383,393-98 (1978); New England Coalition on Nuclear Pollution v. NRC, 582 F.2d 87, 95 (1st Cir. 1978). This comparison included consideration of the economic costs associated with disposal of the wastes at the proposed site and at the alternative sites. See Seabrook, supra, 5 NRC at 533; NECNP, supra, 582 F.2d at 95-96.

Based upon this comparison, the staff does not believe that any of the alternative sites considered is obviously superior to the proposed site. This is supported by the cost-benefit analysis, which shows that none of the sites considered is obviously superior to the proposed site. It is the NRC staff's judgment that the cost of establishing an off-site disposal area, transporting all wastes to the alternative site, and stabilizing the wastes cannot be justified on the basis of reduced health, safety, or environmental impacts, as shown by the cost-benefit analysis. Based on the information and analysis given within this document, the NRC staff concludes that the Proposed Action is the preferred course of action.

1.8 LICENSING ACTION

The licensing action that is supported by the preferred course of action is the renewal of the Kerr-McGee license. The license will be issued to conduct the stabilization activities and to possess, store, and dispose of the wastes on-site; it will have no fixed termination date. Upon transfer of the wastes from the Factory and Intermediate sites to the Disposal Site and after NRC has determined that the Factory and Intermediate sites meet applicable requirements for release for unrestricted use, the Factory and Intermediate sites will be deleted from the license as authorized places of possession of radioactive material. Following a final NRC determination that all applicable regulations have been met, the Kerr-McGee license may be terminated upon completion of the transfer of title to and custody of the Disposal Site and wastes to either the state or federal government under Section 83 of the Atomic Energy Act of 1954, as amended (42 U.S.C. § 2113). NRC oversight of the Disposal Site would, however, continue even after transfer of title and custody to the federal or state government. See Sections 83(b)(5) and 84 of the Atomic Energy Act of 1954 (42 U.S.C. §§ 2113(b)(5) and 2114).

In the interest of protecting public health and safety and environmental values, any license renewal issued to allow on-site waste stabilization will contain conditions to limit exposure to members of the public, protect on-site

workers, and evaluate actual environmental impacts. Accordingly, the following subjects will be addressed as conditions of the license:

1. During stabilization operations -
 - a. Kerr-McGee will be required to have a health-physics plan for protection of workers.
 - b. Environmental monitoring of air and water will be required.
 - c. Conditions designed to limit public exposure and environmental impact will be imposed.
2. After stabilization is complete, but before transfer of the site to the federal or state government -
 - a. An environmental monitoring program will be required.
 - b. An inspection and maintenance program will be required for the stabilized site.

1.9 REFERENCES*

- Kerr-McGee Chemical Corporation. 1986. West Chicago Project Engineering Report. U.S. Nuclear Regulatory Commission, License No. STA-583. Information Transmittal, April 1986. 20 binders.
- Rand McNally. 1986. Commercial Atlas Marketing Guide. 117th ed. Chicago.
- U.S. Bureau of the Census. 1982. Characteristics of the Population. Number of Inhabitants, Illinois. PC80-1-A15. 1980 Census of Population.
- U.S. Nuclear Regulatory Commission. 1983. Final Environmental Statement Related to the Decommissioning of the Rare Earths Facility, West Chicago, Illinois, Docket No. 40-2061, Kerr-McGee Chemical Corporation. NUREG-0904. Office of Nuclear Material Safety and Safeguards. May 1983.
- U.S. Nuclear Regulatory Commission. 1987a. State of Illinois; Staff Assessment of Proposed Agreement between the NRC and the State of Illinois; Republication. Fed. Regist. 52:2309-2324 (January 2, 1987).
- U.S. Nuclear Regulatory Commission. 1987b. Memorandum from S.J. Chilk to H.R. Denton and V. Stello, Jr., May 13, 1987. Subject: SECY-87-104, Proposed Agreement between the State of Illinois and U.S. Nuclear Regulatory Commission Pursuant to Section 274 of the Atomic Energy Act of 1954, as Amended.

*In this reference list, the memo cited is on file. Copies are available upon request from S.Y. Tsai, Energy and Environmental Systems Division, Bldg. 362, Argonne National Laboratory, Argonne, Illinois 60439.

2. PURPOSE AND NEED

2.1 HISTORY AND CURRENT STATUS

2.1.1 Background and Purpose

In 1931, a facility to process ores containing thorium and rare earth metals was established in West Chicago, Illinois. The plant processed 1,800 to 9,100 metric tons (MT) (2,000 to 10,000 tons) of monazite ore per year. Kerr-McGee Chemical Corporation acquired the facility in 1967 and operated it until closing the facility in 1973.

In 1979, Kerr-McGee submitted a plan to the U.S. Nuclear Regulatory Commission (NRC) for decommissioning the inactive West Chicago site and stabilizing the accumulated wastes and tailings. The plan was modified and resubmitted to NRC in 1981. The new plan was reviewed by NRC and, pursuant to the National Environmental Policy Act (NEPA) of 1969 (Public Law 91-190), a Final Environmental Statement (FES) was issued in May 1983. The FES was to serve as the basis for licensing and decommissioning.

In the FES, NRC evaluated several alternatives and proposed that on-site storage in an upgraded disposal cell be approved and that a decision on permanent disposal be deferred until more monitoring data could be accumulated and evaluated with respect to the effectiveness of the stabilization plan. On-site storage was proposed because the basis for evaluating alternatives had not been well established. In particular, standards of the U.S. Environmental Protection Agency (EPA) governing the stabilization and control of uranium and thorium mill tailings and residues, required by the Uranium Mill Tailings Radiation Control Act (Public Law 95-604), had not been published in final form. In addition, NRC criteria for the disposal of mill tailings -- as codified in 10 CFR Part 40, Appendix A -- had been in part temporarily suspended by Congress.

After issuance of the FES, EPA's standards (40 CFR Part 192) were promulgated in final form in the Federal Register on October 7, 1983 (U.S. Environ. Prot. Agency 1983), and the temporary suspension of 10 CFR Part 40, Appendix A, expired. The NRC, as directed by Congress, amended its regulations codified in Appendix A (U.S. Nucl. Reg. Comm. 1985) to conform to the new EPA regulations. Additionally, the NRC has proposed amendments to Appendix A to incorporate therein the EPA's groundwater protection regulations applicable to uranium and thorium mill tailings (U.S. Nucl. Reg. Comm. 1986).

Another new development since the FES was issued is the change in the estimated volume of the Kerr-McGee wastes. In 1984-1986, Kerr-McGee initiated

an extensive testing program on the site; this resulted in a revised estimate of the waste volume on the site, nearly doubling the amount. In addition, materials from off-site areas are being stored on the site. The effect of this new waste volume on the conclusions of the environmental impact analyses described in the FES is evaluated in this Supplemental Environmental Statement.

Major tasks discussed in this supplemental statement include: (1) evaluation of disposal designs and plans for management of wastes at the West Chicago site and alternative sites with respect to applicable EPA and NRC criteria; (2) analysis of the impacts of permanent disposal of the wastes at each site; and (3) assessment of the environmental, social, and economic costs and benefits of waste disposal at each site.

2.1.2. Source Characteristics

From 1954 when thorium processing under license began until plant shutdown in 1973, the Kerr-McGee facility in West Chicago processed about 62,000 MT (68,300 tons) of monazite ore containing about 4.8% thorium dioxide and about 12,000 MT (13,600 tons) of bastnasite, a fluorocarbonate compound containing about 54% rare earth (RE) oxides. An estimated 75% of the contained thorium dioxide and 75% of the contained RE oxides were produced as products; the remaining 25% of each entered the waste stream. Solid-waste components included gangue and unreacted ores, barium sulfate, and insoluble RE and thorium compounds. Liquid wastes were acidified to pH 3 and pumped to sedimentation ponds where waste components either precipitated out as sediments or entered the underlying ground (Kerr-McGee 1980--Chap. 3; Rainey 1980). Estimated amounts of certain chemicals discarded in the waste streams during plant operations from 1954 to 1973 are given in Table 2.1.

Besides pond sediments and ore residues, other wastes exist both on-site and off-site (e.g., building rubble, contaminated soil underlying the site, and other contaminated materials). Estimates of the volumes, densities, and masses of these waste components are given in Table 2.2. The classification of waste components and the volumes of on-site components are given in the engineering report (Kerr-McGee 1986--Vol. IV). The volume of contaminated soil at the Sanitary Treatment Plant is estimated by Kerr-McGee to be the amount of soil that contains thorium-232 at concentrations of 15 pCi/g or more (and presumably 15 pCi/g radium-228, which is in equilibrium with thorium-232) (Kerr-McGee 1985--Exhibits II and IV).

2.1.2.1 Radiological Characterization

Average concentrations of certain radiological species in the waste components are given, along with concentration ranges and standard errors, in

Table 2.1. Amounts of Certain Chemicals Discarded as Wastes from 1954 to 1973

Chemical Species	Amount (MT) ^a
<u>Solid Wastes</u>	
Rare earth oxides	10,000
Barium sulfate	-
<u>Liquid Wastes</u>	
Sodium sulfate	150,000
Sodium chloride	95,000
Sodium fluoride	23,000
Monosodium phosphate	7,800
Ammonium chloride	3,300
Ammonium sulfate	1,300
Calcium chloride	530
Ethylenediaminetetraacetic acid	35
20% solution of 2-ethylhexylphosphate in kerosene	37,800 L ^b

^a The total amounts of chemical components in the liquid wastes were estimated by scaling up the amounts produced per year from 1970 through 1973 (Kerr-McGee 1980--Table 3; Rainey 1980) by the ratio of the total amount of ore processed to that processed per year in the period 1970-1973.

^b This amount (liters) represents excess inventory dumped on the waste pile in 1973.

Source: Data from Rainey (1980).

Table 2.3. The data given for on-site waste components for uranium-238, radium-226, and thorium-232 summarize the results of an extensive sampling and analysis program carried out by Kerr-McGee (1986--Vol. VIII, Exhibit I, Apps. E and F). For the ore tailings, sludge pile, and pond sediments, the number of samples is the sum -- over all relevant boreholes in the tailings, sludge, and sediments, respectively -- of the number of samples taken at different depths at each borehole. For the contaminated soils at each area, the samples chosen by Kerr-McGee to describe the contaminated soils include only those samples for which the sum of the uranium-238, thorium-232, and radium-226 concentrations plus the corresponding accuracies is at least 15 pCi/g.

Table 2.2. Estimated Volumes, Densities, and Masses of Waste Components^a

Source and Type of Material	Volume ^b (m ³)	Density (g/cm ³)	Mass (MT)
<u>Factory Site</u>			
Process equipment and contaminated material ^c	500	-	-
Building rubble ^d	11,800	2.38 ^f	28,100
Steel (structural and equipment) ^e	1,800	4.00 ^f	7,300
Contaminated soil	139,900	1.84 ^f	257,400
<u>Intermediate Site</u>			
Contaminated soil	5,700	1.84 ^f	10,500
<u>Disposal Site</u>			
Ore tailings	18,700	1.55 ^g	29,000
Sludge pile	3,800	1.39 ^g	5,300
Sediments, pond 1	20,600	1.35 ^g	27,900
Sediments, ponds 2, 3, 4, 5	9,900	1.35 ^g	13,400
Neutralization and stabilization agents	3,800	-	-
Contaminated soil	26,700	1.84 ^f	49,100
<u>Residential Areas</u>			
Contaminated soil	26,800 ^h	1.84 ^f	49,300
<u>Sanitary Treatment Plant</u>			
Contaminated soil	9,100 ⁱ	1.84 ^f	16,700

Table 2.2. Continued

Source and Type of Material	Volume (m ³) ^b	Density (g/cm ³)	Mass (MT)
Miscellaneous			
Incinerator ash	300	0.7 ^j	200
Rare earth chemicals	300	1.84 ^k	600
Temporary detention pond sediments	1,900	1.35 ^g	2,500
Total	281,600		

^a Volumes and masses are given to the nearest 100 m³ and 100 MT, respectively.

^b Unless otherwise indicated, volumes are those given in the engineering report (Kerr-McGee 1986--Vol. IV, Table 4-2).

^c Includes steel tanks (30 m³), steel pipe (245 m³), and cement-asbestos (transite) (248 m³) (Kerr-McGee 1986--Vol. IV, Table 4-2).

^d Includes block and brick (6,010 m³), reinforced concrete (4,820 m³), and miscellaneous rubble (920 m³). Rubble from the disposal site is included here.

^e Structural steel sections 40 cm or larger are not included because they are assumed to be candidates for decontamination and removal.

^f Values are those given for concrete rubble, structural steel (50% voids), or soils/clay at another site (Bechtel Natl. 1984--App. F).

^g Values were calculated from the (derived) dry densities and natural moisture contents of the waste components given in Table 3-1 of the engineering report (Kerr-McGee 1986--Vol. III), assuming that wetting the material results in no volume increase over the amount given in the reference.

^h Data from Stauter (1986).

ⁱ Data from Kerr-McGee (1985)

^j Data from FES (Table F.1).

^k Rare earth chemicals are assumed to have the same bulk density as soils.

Table 2.3. Concentrations of Certain Radiological Species in the Waste Components^a

Source and Type of Material	No. of Samples ^b	Concentration (pCi/g) ^a									Avg. Thorium-230 ^d	Avg. Radium-228 ^e
		Uranium-238			Radium-226			Thorium-232				
		Range	Avg.	Std. Error ^c	Range	Avg.	Std. Error ^c	Range	Avg.	Std. Error ^c		
<u>ON-SITE</u>												
<u>Factory Site</u>												
Process equipment and material ^f	-	-	-	-	-	-	-	-	-	-	-	-
Building rubble ^f	-	-	-	-	-	<50 ^g	-	-	100 ^h	-	12	100
Steel (structural and equipment)	-	-	-	-	-	<50 ^g	-	-	100 ^h	-	12	100
Contaminated soil	361	0-1040	118	12	0-578	12.9	3.3	0.1-4120	177	34	21	177 ^h
<u>Intermediate Site</u>												
Contaminated soil	4	14.6-128	43.3	28	0.6-5.1	1.8	1.1	0-26	6.6	16.5	0.77	6.6 ^h
<u>Disposal Site</u>												
Ore tailings	226	0-893	13.7	5.0	6-9398	812	60	40-8445	1360	70	160	5500 ⁱ
Sludge pile	78	0-3426	234	73	0.5-31500	1310	1100	0.3-11050	804	417	94	875 ⁱ
Sediments, pond 1	72	0-2091	66.5	33.1	0-1105	71.1	17.4	28-7752	3140	226	370	3140 ^h
Sediments, ponds 2, 3, 4, 5	68	0-1860	85.8	29.0	0.1-180	13.4	3.4	0.1-2100	211	52	25	211 ^h
Neutralization and stabilization agents	-	-	-	-	-	-	-	-	-	-	-	-
Contaminated soil	171	0-887	42.4	7.4	0-4557	65	31.4	0-6556	187	54	22	187 ^h
<u>Miscellaneous</u>												
Incinerator ash	-	-	-	-	-	<50 ^g	-	-	100 ^h	-	12	100
Rare earth chemicals	-	-	-	-	-	<50 ^g	-	-	100 ^h	-	12	100
Temporary detention pond sediments	-	-	-	-	-	-	-	-	-	-	-	-

Table 2.3. Continued

Source and Type of Material	No. of Samples ^b	Concentration (pCi/g) ^a									Avg. Thorium- 230 ^d	Avg. Radium- 228 ^e
		Uranium-238			Radium-226			Thorium-232				
		Range	Avg.	Std. Error ^c	Range	Avg.	Std. Error ^c	Range	Avg.	Std. Error ^c		
<u>OFF-SITE</u>												
<u>Residential Areas</u>												
Contaminated soil	-	-	-	-	-	-	-	-	-	-	-	-
<u>Sanitary Treatment Plant</u>												
Contaminated soil	29	-	67.5 ^j	-	<0.46-42 ^k	9.9 ^k	-	15-2510	180 ^k	-	22 ^j	180 ^h

^a Unless otherwise indicated, concentrations for all on-site materials are measured in pCi/g dry weight (Kerr-McGee 1986--Vol. VIII, App. A). A hyphen indicates that insufficient data are available to make estimates.

^b Number of samples includes depth profiles at several locations in the waste.

^c Standard error is the standard deviation of the average.

^d Thorium-230 concentrations were estimated by the methods described in the text.

^e Data from Kerr-McGee (1983), unless otherwise indicated.

^f See footnotes c, d, and e in Table 2.2 for further description.

^g Data from FES (App. F).

^h Values obtained by assuming that thorium-232 and radium-228 activities are equal.

ⁱ Concentrations of 428 pCi/g thorium-232 and 3,089 pCi/g radium-228 were measured in 1979 in one sample of ore tailings. Concentrations measured for one sludge sample in 1979 were 4,847 pCi/g thorium-232 and 5,725 pCi/g radium-228 (Kerr-McGee 1980--Chap. 3). The radium-228 values were corrected for decay and ingrowth to 1985 to give 1,727 pCi/g (ore tailings sample) and 5,275 pCi/g (sludge sample). The values in the table were estimated by multiplying average thorium-232 concentrations by the 1985 ratios (radium-228/thorium-232 concentrations for the samples). This method estimates the average radium-228 concentration from values obtained from one sample by assuming that inhomogeneities in the piles will affect the radium-228/thorium-232 concentration ratio less than the concentrations of either species.

^j Values obtained by multiplying the thorium-230/thorium-232 and uranium-238/thorium-232 concentration ratios by the thorium-232 concentration. The ratios are obtained as averages of the ratios obtained for those few samples for which thorium-232, thorium-230, and uranium-238 concentrations were measured for each sample. Data from Kerr-McGee (1985--Exhibit III, App. D).

^k Data from Kerr-McGee (1985). The average thorium-232 and radium-226 concentrations for the Sanitary Treatment Plant soils were determined as weighted averages of the averages for each component material. The weights were taken to be the volume fractions for each component. Includes background values.

Source: Unless otherwise indicated, data are from Kerr-McGee (1986--Vol. VIII, Exhibit I, App. F).

At several borehole locations at the Factory Site, contamination was found to extend to 8.2 m (27 ft) below the surface into the E stratum; at four borehole locations, contamination extended into the D stratum (these strata [layers] are described in Section 4.6.1). At one borehole location at the Intermediate Site, contamination was found in the E stratum about 4.9 m (16 ft) below the surface. At the Disposal Site, 43 borehole locations contained contaminated soil. Contamination extended to a depth of 8.2 m (27 ft) below the surface (through the E stratum and into the D stratum at one location). Contamination was found in the tailings pile to a depth of 8.5 m (28 ft), which is down to ground elevation and below. Contamination also extended throughout the sludge pile down to ground elevation and below. At ponds 1, 2, and 3, contamination extended below the pond bottoms into the D stratum (Kerr-McGee 1986--Vol. VII, Exhibit I, Apps. E and F).

The average concentrations of uranium-238 for on-site locations ranged from 14 pCi/g in the ore tailings at the Disposal Site to 234 pCi/g in the sludge pile. No data have been reported regarding the on-site concentration ratios between uranium-238 and the other uranium isotopes, uranium-234 and uranium-235. Consequently, it was assumed that these isotopes are present in their natural activity ratios (uranium-238:uranium-234:uranium-235 = 1:1:0.046). The average concentrations of radium-226 at the different on-site locations ranged from 1.8 pCi/g (essentially background) at the Intermediate Site to 1,310 pCi/g in the sludge pile. The average concentrations of thorium-232 ranged from 6.6 pCi/g at the Intermediate Site to 3,140 pCi/g in pond 1 sediments.

The average concentrations of 180 pCi/g thorium-232 and 9.9 pCi/g radium-226 for the Sanitary Treatment Plant (Table 2.3) are averages over all sample concentrations that contain at least 15 pCi/g of thorium-232. This concentration of thorium-232, which is in equilibrium with radium-226, represents the EPA guideline limit for subsurface thorium by-product materials (40 CFR Part 192). Radium-226 concentrations are much lower, so it was sufficient to use thorium concentrations to determine the extent of contamination.

The three samples selected for further radiological analysis had an average thorium-230/thorium-232 ratio of 0.124. The ratios of uranium-238/thorium-232 (0.042), uranium-234/uranium-238 (1.00), and uranium-235/uranium-238 (0.043) were also determined (Kerr-McGee 1985--Exhibit III, App. D). These ratios, along with the average thorium-232 concentration, were used to estimate the average uranium-238 and thorium-230 concentrations of 7.5 pCi/g and 22 pCi/g, respectively. Based on the uranium isotope ratios, the isotopes are present in approximately natural equilibrium.

Except for the Sanitary Treatment Plant, data are not available on thorium-230 concentrations in the waste components. (Values measured for the ore tailings pile and sludge pile are for one sample taken at one location in each pile [Kerr-McGee 1980--Attach. 1 to App. B] and thus are not representative of average concentrations in the piles.) However, the thorium-230 concentrations were estimated as follows. It was assumed that the uranium-238 in the wastes was present in the monazite ore as a contaminant and that the uranium was in secular equilibrium with all members of the decay chain. This assumption is reasonable because the total inventories of uranium-238 (31 Ci) and radium-226 (35 Ci), as calculated from the data in Table 2.3, are about equal. It was also assumed that essentially all the original radium-226 inventory of the original monazite ore ended up somewhere in the wastes. As a result, the total inventory of thorium-230 in the original monazite ore is estimated to be 35 Ci. Because thorium-230 and thorium-232 are the same element chemically, it was assumed that thorium-230 and thorium-232 behaved the same in all process steps and that the average thorium-230 to thorium-232 concentration ratio has the same value in each waste component.

Based on the above assumptions and the estimate that about 300 Ci of thorium-232 was processed during the plant lifetime (62,000 MT monazite ore containing 4.8% thorium dioxide), thorium-230 concentrations were obtained by multiplying average thorium-232 concentrations by the ratio 35/300. The results are given in Table 2.3. The accuracy of the average concentrations given in Table 2.3 varies widely over the different waste components and radionuclides. For example, for radium-226 in the sludge pile, the standard error (which gives the statistical reliability of the mean) of 1,100 pCi/g is almost as large as the average of 1,310 pCi/g. For thorium-232 at the Intermediate Site, the standard error (16.5 pCi/g) is larger than the average (6.6 pCi/g). For other cases (e.g., thorium-232 in the ore tailings), the standard error is much smaller than the average.

The average concentrations of thorium-230 given in Table 2.3 are values that were estimated because good data were not available. The reliability of the method of estimation is supported by the fact that the value given for the Sanitary Treatment Plant, which is based on measured thorium-230 concentrations, is very close to the value that would be obtained by the method used for the other waste components.

No radiological data were available for the off-site residential areas or the temporary detention pond sediments. The radium and thorium values given in Table 2.3 for building rubble, steel, incinerator ash, and rare earth chemicals are probably crude estimates because the references (FES--App. F; Kerr-McGee 1983) do not give details on how the values were obtained.

There is great variability in the individual sample concentrations for each waste component, as evidenced by the range of uranium-238, thorium-232, and radium-226 concentrations given in Table 2.3. This is supported by a study of the original sample data (Kerr-McGee 1986--Vol. VIII, Exhibit I), which shows that the waste components are quite heterogeneous.

Inventories of radioactive species estimated from the data in Tables 2.2 and 2.3 are presented in Table 2.4. The total inventories include contributions from most of the waste components. The high inventory of radium-228 compared with that for thorium-232 in the ore tailings is a consequence of the higher nonequilibrium concentration listed in Table 2.3. Rough mass-balance calculations* show that the total inventory of radium-228 for 1985 should be about 130 Ci, which is lower than the value of 200 Ci given in Table 2.4. The total thorium-232 inventory of 120 Ci is equivalent to an inventory of about 1,200 MT thorium dioxide in the wastes. Most of it is contained in the contaminated soil under the Factory Site, the ore tailings pile, and the pond 1 sediments. Much of the radium-226 inventory is in the ore tailings (16 Ci), and most of the uranium-238 inventory (26 Ci) is in the contaminated soil under the Factory Site. The inventories of uranium-234 and uranium-235 are likely to be present in each waste component in amounts given by the natural activity ratios with uranium-238 (uranium-238:uranium-234:uranium-235 = 1:1:0.046). Sufficient data are not available to determine the inventories of contaminated soils from residential areas.

2.1.2.2 Chemical Characterization

Some data are available on the chemical characteristics of the waste components. Fourteen samples were taken from seven boreholes: two in the ore tailings, drilled to 5.2 m (17 ft); two in the sludge pile, drilled to 3.4 m (11 ft); two in the pond 1 sediments, drilled to 4.4 m (14.5 ft); and one in the pond 2 sediments, drilled to 2.7 m (9 ft). These samples were analyzed for priority pollutant metals, priority and nonpriority organic pollutants (based on the Resource Conservation and Recovery Act, RCRA), pesticides, and polychlorinated biphenyls (PCBs). In addition, 234 samples from the Disposal Site, Intermediate Site, and Factory Site were analyzed for soil pH, conductivity, and total organic carbon (TOC); the results are summarized in Tables 2.5 and 2.6 (details are given in Kerr-McGee [1986--Vol. VIII]).

*The amount of radium-228 contributed by the monazite processed during the period 1954-1973 was about 290 Ci. If it is assumed that this amount was all contributed in 1958 (most was contributed in 1954-1962) (Rainey 1980), then accounting for decay of the original 290 Ci of radium-228 (half-life is 5.8 years) and ingrowth from decay of the 120 Ci thorium-232 in the waste components from 1958 to 1985 gives a total 1985 inventory of 130 Ci of radium-228.

Table 2.4. Estimated Radiological Inventory of the Different Waste Components^a

Source and Type of Material	Mass ^b (MT)	Inventory (Ci)				
		Uranium- 238	Radium- 226	Thorium- 232	Thorium- 230	Radium- 228
<u>Factory Site</u>						
Process equipment and contaminated material	-	-	-	-	-	-
Building rubble	28,100	-	<1.4	2.8	0.33	2.8
Steel (structural and equipment)	7,300	-	<0.36	0.73	0.085	0.73
Contaminated soil	222,400 ^C	26	2.9	39	4.6	39
<u>Intermediate Site</u>						
Contaminated soil	9,100 ^C	0.39	0.016	0.060	0.007	0.060
<u>Disposal Site</u>						
Ore tailings	19,300 ^C	0.26	16	26	3.0	110
Sludge pile	3,400 ^C	0.79	4.4	2.7	0.32	3.0
Sediments, pond 1	11,500 ^C	0.76	0.82	36	4.2	36
Sediments, ponds 2, 3, 4, 5	5,500 ^C	0.47	0.07	1.2	0.14	1.2
Neutralization and stabilization agents	-	-	-	-	-	-
Contaminated soil	42,400 ^C	1.8	2.7	7.9	0.92	7.9

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Table 2.4. Continued

Source and Type of Material	Mass ^b (MT)	Inventory (Ci)				
		Uranium- 238	Radium- 226	Thorium- 232	Thorium- 230	Radium- 228
<u>Miscellaneous</u>						
Incinerator ash	200	-	<0.01	0.02	0.002	0.02
Rare earth chemicals	600	-	<0.03	0.06	0.007	0.06
Temporary detention pond sediments	1,100 ^c	-	-	-		-
<u>Residential Areas</u>						
Contaminated soil	49,300	-	-	-	-	-
<u>Sanitary Treatment Plant</u>						
Contaminated soil	16,700	0.12	0.17	3.0	0.36	3.0
TOTAL	416,900	31	29	120	14	200

^a Inventories are the product of the concentrations (see Table 2.3 and the mass in column 2); they are reported to two significant figures.

^b Unless otherwise indicated, the mass is that given in Table 2.2.

^c Value is a dry mass calculated from the volumes given in Table 2.2 and the dry densities of 1.59 g/cm³ (contaminated soil), 1.03 g/cm³ (ore tailings), 0.90 g/cm³ sludge, and 0.56 g/cm³ (pond sediments) (Kerr-McGee 1986--Vol. III, Table 3-1).

Table 2.5. Concentrations of RCRA Priority Pollutant Metals and Other Parameters in the Waste Components

Parameter	Average Concentrations (ppm) ^a						
	Factory Site	Intermediate Site	Disposal Site				
			Ore Tailings	Sludge Pile	Pond 1 Sediments	Pond 2 Sediments	Contaminated Soil
Antimony	-	-	13	18	14	26	-
Arsenic	-	-	1.9	1.5	<1.2	4.2	-
Beryllium	-	-	<1	<1	<1	<1	-
Cadmium	-	-	0.78	0.80	0.65	0.85	-
Chromium	-	-	6.7	22	16	30	-
Copper	-	-	42	34	20	11	-
Lead	-	-	1700	740	57	31	-
Mercury	-	-	0.48	0.10	2.5	0.045	-
Nickel	-	-	23	8.9	4.0	20	-
Selenium	-	-	<69	<60	<60	<60	-
Silver	-	-	8.7	0.91	1.4	0.8	-
Thallium	-	-	<10	<10	<10	<10	-
Zinc	-	-	3.2	110	200	38	-
Phenol	-	-	<0.002	<0.002	<0.0071	<0.002	-
Cyanide	-	-	<22	<72	<76	1.1-1.6 ^b	-
TOC (% dry wt)	0.67(562)	0.44(146)	0.42(125)	1.0(72)	0.88(108)	0.52(184) ^c	0.54(625)
pH (pH unit)	7.33(562)	8.06(146)	3.54(125)	6.56(72)	6.44(108)	7.64(184) ^c	7.86(625)

^a All concentrations are rounded to two significant figures. A hyphen indicates that no data are available. Concentration units are parts per million unless otherwise indicated. Concentrations of metals, phenol, and cyanide refer to wet materials. The numbers in parentheses are the number of samples used to generate the average. The metal, phenol, and cyanide values are averages of two samples for all sites except pond 2; pond 2 values are for one sample only.

^b The upper value, 1.6, was calculated by assuming that each detection limit is a real value. The lower value, 1.1, was calculated by replacing each detection limit by the value 0.

^c Average of samples from ponds 2, 3, 4, and 5.

Source: Kerr-McGee (1986--Vol. VIII, Exhibit I).

Table 2.6. Concentrations of RCRA Priority Organic Pollutants and Pesticides
Detected in the Waste Components^a

Chemical Species	Concentration (ppb)							
	Sludge Pile		Ore Tailings		Pond 1 Sediments		Pond 2 Sediments	
	0-5 ft	5-11 ft	0-9 ft	9-17 ft	0-10 ft	10-14 ft	0-5 ft	5-9 ft
<u>Priority Pollutant Organics</u>								
Methylene chloride	-	-	-	-	-	50,22 ^b	-	-
Fluoranthene	1,550	230	-	-	-	400	-	-
Bis (2-ethylhexyl) phthalate	220	190	-	270	-	-	440	-
Di-n-butyl phthalate	510	600	-	570	300	-	440	490
Benzo(a)anthracene	500	-	-	-	-	-	-	-
Benzo(a)pyrene	340	-	-	2,000	-	-	-	-
Benzo(k)fluoranthene	1,230	-	-	1,900	-	-	-	-
Chrysene	650	-	-	-	-	-	-	-
Anthracene	140	-	-	-	-	-	-	-
Phenanthrene	1,020	350	-	-	-	410	-	-
Pyrene	800	190	-	-	-	380	-	-
Diethyl phthalate	250	-	-	200	250	-	180	230
<u>Pesticides</u>								
β -Benzene hexachloride	-	-	10	-	-	-	-	-

^a Each column of data is headed by the waste component and the depth range to which it applies. A hyphen indicates that no chemical was detected at the detection level for that sample.

^b The two concentrations refer to two different locations at about the same depth range.

Source: Kerr-McGee (1986--Vol. VIII, Exhibit I).

Appreciable concentrations of metals occur in the Disposal Site wastes (Table 2.5). Average concentrations of lead in the ore tailings and sludge pile are 1,700 parts per million (ppm) and 740 ppm, respectively. Average concentrations of copper, chromium, and nickel range from 4.0 to 42 ppm. The pond 1 sediments contain 200 ppm zinc and 2.5 ppm mercury. Concentrations of selenium and cyanide (except for pond 2) are given as detection limits, which are so high that they are meaningless. The range of cyanide values for pond 2 is explained by the fact that the one individual value used to compute the average was a real value and the rest were detection limits. The concentrations given in Table 2.5 for metals, phenols, and cyanide are given as parts per million or as milligrams per kilogram wet weight; concentration values given in terms of milligrams per kilogram dry weight would be higher. For example, dry weight concentrations of the sediments and sludge would be higher by factors of 2.4 and 1.6, respectively. The only acidic waste component is the ore tailings pile with a pH of 3.54; the other components are approximately neutral (Table 2.5).

The results of testing some of the Disposal Site waste components for pollutant organics and pesticides are given in Table 2.6. The concentrations of most of the 14 samples tested were below the detection limits (indicated by hyphens in the table). For some samples, detection limits are quite high -- up to 1,500 parts per billion (ppb) for priority organics and 160 ppb for some PCBs (Kerr-McGee 1986--Vol. VIII, Exhibit I).

Some priority pollutant organics were present at concentrations ranging up to 2,000 ppb, e.g., benzo(a)pyrene in the ore tailings (Table 2.6). Some of the organic pollutants detected in the sludge pile at depths of 0 to 1.5 m (0 to 5 ft) are typical constituents of coal tar or asphalt and may be derived from the asphalt used to cover the pile. Phthalates are used as plasticizers in many vinyl and plastic materials and are becoming widespread in the environment (Kerr-McGee 1986--Vol. VIII, Exhibit I). Only one waste component, the ore tailings pile, had positive results for the presence of a pesticide (β -benzene hexachloride); however, its concentration (10 ppb) is barely above the detection limit of 8 ppb.

The waste components have been tested in some detail to determine whether they are hazardous wastes as defined by RCRA. These tests (EP toxicity tests, as described in 40 CFR Part 261) were carried out on many samples, and the results were analyzed statistically (Kerr-McGee 1986--Vol. VIII, Exhibit I). The results are summarized in Table 2.7 as 99% upper confidence limits for each metal. Comparison of the concentrations given in Table 2.7 with the EP toxicity limits (second column) shows that the upper 99% confidence limit concentrations for lead and arsenic from the tailings pile, 3.3 mg/L and 3.9 mg/L, respectively, are close to the EP toxicity limit of 5 mg/L. The

Table 2.7. Concentrations, at the 99% Upper Confidence Limit, of the EP Toxicity Test Means for Metals in Some of the Waste Components^a

EP Toxicity ^b		Factory Site (mg/L)		Intermediate Site (mg/L)	Disposal Site (mg/L)				
Metals	Limits (mg/L)	North (154)	South (217)	Contaminated Soil (6)	Contaminated Soil (112)	Pond 1 Sediments (15)	Ponds 2-5 Sediments (72)	Sludge Pile (15)	Tailings Pile (21)
Silver	5	0.044	0.025	0.017	0.043	0.017	0.009	0.22	1.9
Arsenic	5	0.28	0.26	0.48	0.30	0.27	0.20	0.63	3.3
Barium	100	0.48	0.18	0.21	0.26	0.26	0.25	0.11	3.4
Cadmium	1	0.010	0.040	0.007	0.011	0.009	0.006	0.019	0.10
Chromium	5	0.038	0.018	0.049	0.029	0.016	0.016	0.023	0.28
Mercury	0.2	0.0012	0.00041	0.00020	0.00094	0.0012	0.00074	0.00028	0.0078
Lead	5	0.17	0.24	0.21	0.15	0.27	0.16	1.1	3.9
Selenium	1	0.12	0.11	0.15	0.097	0.097	0.11	0.10	0.20

^a The numbers in parentheses indicate the number of samples analyzed for each waste component. Confidence limit values are rounded to two significant figures.

^b Limits are from 40 CFR Part 261.

Source: Kerr-McGee (1986--Vol. VIII, Exhibit I).

value for silver for the tailings pile (1.9 mg/L) is also appreciable compared with the limit of 5 mg/L. All other concentration limits in the table are 20% or less of the EP toxicity limits for metals.

Because the concentrations in Table 2.7 are 99% upper confidence limits, it is fairly certain that the on-site wastes are not RCRA hazardous as far as the metal parameters are concerned. (This assessment assumes that the samples chosen for each waste component give an unbiased representation of the component and that no sources of systematic error are present whose removal would raise the test concentrations above the EP toxicity limits.) No test results were reported for the off-site waste components. However, on the basis of the data presented, it appears likely that the off-site waste components are not RCRA hazardous for metals.

EP toxicity tests were also carried out for pesticides and herbicides on 14 samples taken from the tailings pile, the sludge pile, and sediments from ponds 1 and 2 (these are parts of the same samples, described earlier, that were analyzed for RCRA pollutants [Kerr-McGee 1986--Vol. VIII, Exhibit I]). The resulting EP concentrations were 3% or less of the EP toxicity limits for all pesticides (lindane, endrin, methoxychlor, and toxaphene) and herbicides (2,4-D and silvex) for all samples. Consequently, the waste components sampled are also not RCRA hazardous for pesticides and herbicides. No data are available for contaminated soil from the Factory Site, the Intermediate Site, or the Disposal Site, or for off-site waste components. However, on the basis of data obtained thus far, it appears likely that these waste components are also not RCRA hazardous for pesticides and herbicides.

2.2 EPA STANDARDS

The basic standards promulgated by EPA in 40 CFR Part 192 for stabilization and closure of tailings from uranium and thorium mills are as follows (40 CFR Part 192.32; 192.41):

- For radiological hazards, the method of stabilization shall provide reasonable assurance that
 - a. The method will be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, and
 - b. The emission of radon-222 and radon-220 to the atmosphere will not exceed an average emission rate of 20 pCi/(m²·s) (this is a design standard; monitoring for radon emission following closure of the site is not required).

- For nonradiological hazards, the provisions of the Solid Waste Disposal Act (SWDA) shall apply to the extent that the stabilization and closure plan must (40 CFR Part 264.111)

- a. Minimize the need for maintenance after closure, and
- b. "Control, minimize, or eliminate, to the extent necessary to prevent threats to human health and the environment, post-closure escape of hazardous waste, hazardous waste constituents, leachate, contaminated rainfall, or waste decomposition products to the ground or surface waters or to the atmosphere."

The EPA groundwater protection standards that are applicable to the management of thorium by-product materials prior to the end of the closure period are specified in 40 CFR Part 192.32(a)(2). The maximum allowable groundwater concentrations of hazardous constituents (40 CFR Part 264.94 and 40 CFR Part 192.32), unless alternative limits are established, are presented in Table 2.8.

2.3 NRC STANDARDS

The NRC standards for determining the acceptability of Kerr-McGee's decommissioning plan are set forth in Appendix A to 10 CFR Part 40, entitled "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content." NRC was directed by Congress to conform its regulations to the EPA standards, as codified in 40 CFR Part 192; part of that conformance was achieved by NRC's October 16, 1985, amendment of Appendix A to 10 CFR Part 40 (U.S. Nucl. Reg. Comm. 1985). The remaining EPA regulations, primarily those dealing with groundwater protection, are the subject of a further proposed conforming amendment to Appendix A (U.S. Nucl. Reg. Comm. 1986). Even though NRC has not yet amended Appendix A with respect to groundwater protection so that it is in conformance with applicable EPA standards, NRC is required to implement and enforce those standards during the conduct of NRC licensing activities (U.S. Nucl. Reg. Comm. 1985).

2.4 STATE OF ILLINOIS STANDARDS

The state of Illinois also has water quality standards that are applicable to surface water and groundwater (Illinois Administrative Code, Title 35: Environmental Protection Subtitle C: Water Pollution). The relevant standards are the general use water quality standards that must be

Table 2.8. Maximum Concentration of Constituents for Groundwater Protection

Constituent	Maximum Concentration (ppb) ^a
Arsenic	50
Barium	1,000
Cadmium	10
Chromium	50
Lead	50
Mercury	2
Molybdenum	Background
Selenium	10
Silver	50
Thorium	Background
Uranium	Background
Radium-226 and radium-228	5 pCi/L
Gross alpha particle activity	15 pCi/L
Endrin	0.2
Lindane	4
Methoxychlor	100
Toxaphene	5
2,4-D	100
2,4,5-TP Silvex	10

^a In parts per billion, except as noted.

^b Excluding radon and uranium.

Source: 40 CFR Part 264.94 and 40 CFR Part 192.32.

met by surface water and groundwater. In addition, groundwater that is a current or potential source of water for use by the public or in food processing is subject to public use and food processing water standards (35 Ill. Adm. Code Part 302, Subpart C). The state also limits concentrations of chemical species in effluents discharged to state waters (35 Ill. Adm. Code Part 304). The relevant state water quality standards are given in Table 2.9.

The Illinois water quality standards would apply to surface water or groundwater discharges from all the alternative disposal sites considered, with regard to both the effluent standards and the general use water quality standards. The public and food processing water supply standards would apply if the groundwater receiving the effluent was being used or had potential use by the public for such purposes.

Table 2.9. Illinois State Water Quality Standards^a

Parameter	Concentration (mg/L) ^b		
	General Use	Public ^c	Effluent ^d
Arsenic	1.0	0.05	0.25
Barium	5.0	1.0	2.0
Boron	1.0	1.0	-
Cadmium	0.05	0.01	0.15
Chloride	500	250	-
Chromium (hexavalent)	0.05		0.1 (hexavalent)
Chromium (trivalent)	1.0	0.05	1.0 (total chromium)
Copper	0.02	0.02	0.5
Cyanide	0.025	0.025	0.1
Fluoride	1.4	1.4	15
Iron	1.0	1.0	2.0
Lead	0.1	0.05	0.2
Manganese	1.0	0.15	1.0
Mercury	0.0005	0.0005	-
Nitrate (N)	-	10	-
Nickel	1.0	1.0	1.0
Phenols	0.1	0.001	0.3
Selenium	1.0	0.01	-
Silver	0.005	0.005	0.1
Sulfate	500	250	-
Total dissolved solids	1,000	500	15
Zinc	1.0	1.0	1.0
Gross beta (pCi/L)	100	100	-
Radium-226 (pCi/L)	1	1	-
Strontium-90 (pCi/L)	2	2	-

^a Source: 35 Ill. Adm. Code Parts 302, 303, and 304.

^b Concentrations in mg/L unless specified otherwise.

^c These standards must be met by all designated waters at the point at which water is drawn for treatment and distribution as a potable supply or for food processing. Standards for organic pesticides include aldrin, 1 µg/L; chlordane, 3 µg/L; DDT, 50 µg/L; dieldrin, 1 µg/L; endrin, 0.2 µg/L; heptachlor 0.1 µg/L; lindane, 4 µg/L; methoxychlor, 100 µg/L; toxaphene, 5 µg/L; 2,4-D, 100 µg/L; and 2,4,5-TP (silvex), 10 µg/L.

^d These effluent standards include background concentrations and do not apply when influent water exceeds the standards or the incidental addition of small amounts of materials occurs (35 Ill. Adm. Code Part 304.103).

2.5 REFERENCES*

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- Rainey, J.L. 1980. Letter from J.L. Rainey (President, Kerr-McGee Chemical Corporation, Oklahoma City, Okla.) to W. Nixon (Uranium Fuel Licensing Branch, U.S. Nuclear Regulatory Commission, Washington, D.C.), regarding License No. STA-583, Docket No. 40-261. With attachment: "Kerr-McGee's Response to Questions/Comments on the Stabilization Plan Submitted August 15, 1979." April 29, 1980.
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- U.S. Environmental Protection Agency. 1983. Environmental Standards for Uranium and Thorium Mill Tailings at Licensed Commercial Processing Sites; Final Rule (40 CFR Part 192). Fed. Regist. 48(196):45926-45947 (October 7, 1983).

*In this reference list, all letters and memos cited are on file. Copies are available upon request from S.Y. Tsai, Energy and Environmental Systems Division, Bldg. 362, Argonne National Laboratory, Argonne, Illinois 60439.

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3. DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

3.1 COMMON ACTIVITIES

A number of activities in the Proposed Action and alternatives to it would be similar. These common activities include cleanup of the West Chicago site; treatment, transport, and handling of the wastes; preparation of the disposal site; receipt and emplacement of the wastes; and post-closure maintenance and monitoring. These common activities are described in Sections 3.1.1 through 3.1.4; activities that are specific characteristics of the Proposed Action and its alternatives are described in Sections 3.2 through 3.6.

3.1.1 Cleanup of the West Chicago Site

The initial cleanup operations at the West Chicago site have included demolition of buildings, collection of all on-site materials, decontamination of the property, and incineration of some organic low-specific-activity (LSA) wastes. Dust-suppression practices are being used in the cleanup, e.g., water sprays on ore residues and contaminated soils, and foams during demolition of the buildings.

Another cleanup operation would involve excavation of the bottoms of the ponds formerly used for settling of suspended solids. Within each pond, excavation would continue downward until sampling and analysis indicated that the remaining materials were clean according to EPA criteria for radioactivity in soils of restored areas. The excavated soils would be transferred to a disposal cell for containment.

Materials that would be contained in a disposal cell after appropriate treatment include building rubble, ore residues, contaminated earth, some factory metals, and pond sediments. Waste-treatment operations would be applied selectively, depending on the waste type (Kerr-McGee 1981), and would include incineration, crushing of equipment, and neutralization of acidic ore residues. Some of the organic LSA wastes present on the West Chicago site are being incinerated and the resulting ash is being packaged for later placement in the disposal cell. Experience obtained by Kerr-McGee in the incineration of organic LSA wastes has shown that the release of uranium from the off-gas is 10^{-12} to 10^{-14} Ci gross alpha per cubic meter of air and, therefore, is below the applicable limits given by 10 CFR Part 20.

Restoration of the West Chicago site would involve the following activities. Wells previously used for water sources would be plugged. The only wells remaining on the site would be those necessary for monitoring the performance of the disposal cell if this option were selected. Excavation of

contaminated materials from the Factory Site would begin at the less contaminated north end of the site and move progressively to the more contaminated south end. Restoration of the Factory Site would proceed continuously as the excavation work moved southward. Excavated areas on the Factory Site would be backfilled with granular material, such as sands and gravels, to within 0.6 m (2 ft) of the surface and then covered with topsoil and seeded with grass. Cleanup operations would be continued until the soil was in compliance with appropriate NRC guidelines. The area would then be graded, landscaped, and released for unrestricted use.

3.1.2 Transport and Handling of the Wastes

The wastes would be transported to the disposal area by truck, some in packages and some in bulk, according to specific radioactivity (Section 5.9.1.1). Sprinklers, hand-held sprays, and water-truck sprays would be used for dust abatement at the points of loading and unloading bulk shipments. Haul roads on the site would also be sprayed by a water truck to control dust. Materials that did not require packaging during transport would be dampened before departure and would be covered with tarps.

3.1.3 Operations at the Waste-Disposal Site

Preparation of the disposal site and partial construction of the disposal cell would precede receipt of the wastes. Site preparation includes, at an early stage, characterization of the background radioactivity in the area as determined by samples from monitoring wells, surface waters, and air. Prior to construction of the disposal cell, the area would be excavated and contoured, and ancillary facilities would be constructed -- such as a parking lot, access roads, a change house, an administration office, sanitary facilities, and a vehicle washdown area. A security system, with fences and gates, would also be established.

Facilities would be installed for treatment of the wastewater resulting from equipment washdown, precipitation runoff, laundry, and dewatering of the wastes in the disposal cell; sanitary wastewater would require a separate treatment system. Before discharge, some wastewater might require only sedimentation whereas some might require decontamination to remove radioactivity. Treatment to remove radioactivity would probably involve demineralization, which could be handled either by fixed installations or by mobile units supplied by vendors servicing a number of customers on a regular circuit.

Waste receipt and emplacement operations would be accompanied by standard monitoring of personnel, environment, and transportation equipment. Spraying with water for dust suppression would be used in unloading and emplacing soils and ore residues. For Alternatives A-D, in which the wastes would be moved

off-site from the West Chicago location, washdown facilities would be installed at the disposal area and used for decontamination of trucks before they entered public roads.

3.1.4 Postclosure Activities

Postclosure activities would consist of controlling access to the disposal area, monitoring and surveillance, maintenance, and, if necessary, additional remedial action. Monitoring activities would assess potential impacts as follows:

- Groundwater - monitoring of wells for the radiological and chemical parameters that are representative of the wastes,
- Disposal cell cover - air monitoring for radon-222,
- Physical stability of the cell and cell cover - inspection and correction of any subsidence or erosion, and
- Surface water - monitoring of surface runoff leaving the site to determine water treatment or maintenance actions.

3.2 PROPOSED ACTION - ABOVE-GRADE DISPOSAL AT THE WEST CHICAGO SITE

Under the Proposed Action, remedial activities at the West Chicago site would involve containment of all materials contaminated with uranium and thorium in a new disposal cell to be constructed on the south end of the Kerr-McGee property at the West Chicago site. The layout of the Kerr-McGee property at West Chicago after the collection and containment of the wastes is shown in Figure 3.1.

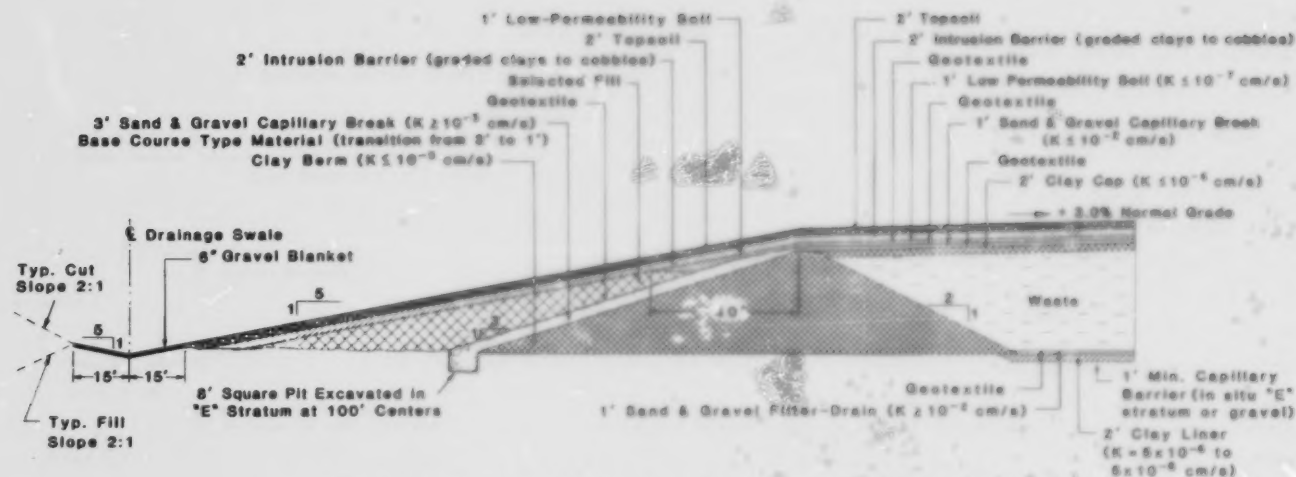
The design of this disposal cell, in which the wastes would be above grade level, is described in detail in Appendix B, Section B.2; a cross section of the conceptual design is presented in Figure 3.2. The above-grade disposal cell described in this analysis is different from the cell proposed in the FES and is based on recent engineering studies sponsored by Kerr-McGee (1986). Construction of the disposal cell would proceed from south to north.

3.2.1 Construction of the Disposal Cell

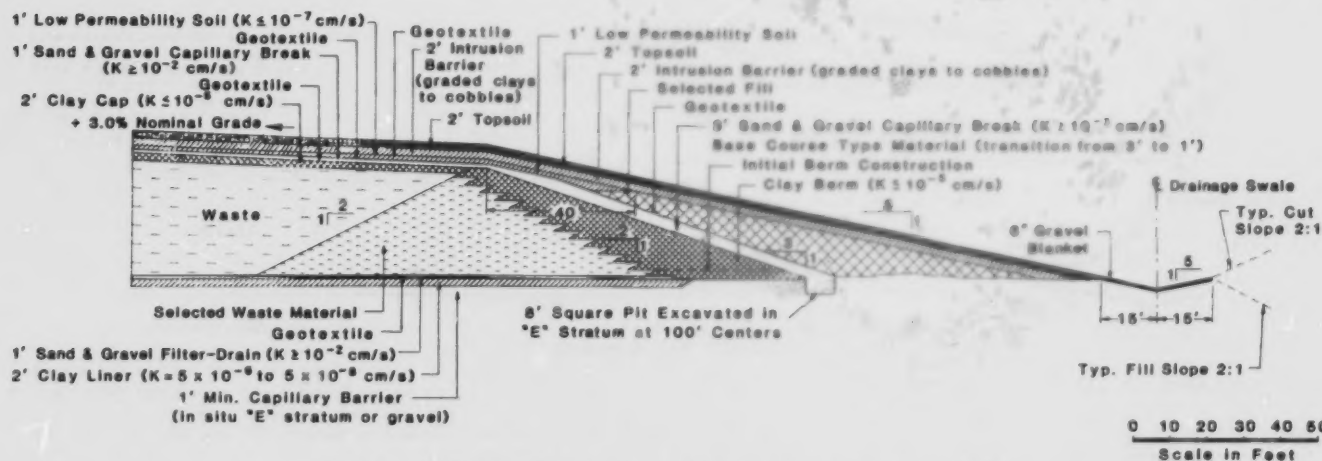
Prior to construction of the cell, a peripheral drainage swale would be constructed across the southern portion of the disposal site, extending approximately 183 m (600 ft) north along the west and east sides. The permanent detention pond would also be constructed at this time.



Figure 3.1. Layout of the Kerr-McGee Site after Cleanup and Disposal.
Source: Modified from Kerr-McGee (1986--Vol. IX).



Typical Berm Section - South And West Sides



Typical Berm Section - North And East Sides

Figure 3.2. Conceptual Design of Above-Grade Disposal Cell: Details of Cross-Sectional Structure.
Source: Redrawn from Kerr-McGee (1986--Vol. IV).

After construction of the swale, initial north and south berm sections would be constructed (Appendix B, Section B.2). Next, the cell base and liner would be prepared using the uppermost clay layer at the site (the F stratum). The clay liner would be placed and compacted in 30-m (100-ft) wide increments beginning at the south end of the disposal cell and proceeding north. After placement of the clay liner, the sand and gravel filter-drain and leachate monitoring system would be installed.

Following placement of the liner and leachate system, the initial portion of the east berm would be built. It would then be possible to begin placing waste materials in the pocket provided by these berms to a level just below the berm tops. Thereafter, the berms would be raised, and the east and west berms would be extended further north as additional waste materials were placed in the cell. The wastes would be placed in the cell in 30-m (100-ft) strips to control contaminated drainage and minimize the amount of waste surface area exposed. Any storm water that percolated through the wastes during construction would be removed by pumping from the leachate monitoring system.

During construction of the disposal cell, a temporary cover would be placed over the exposed top surface of waste portions that had reached their full height within the cell. The temporary cover would minimize dust, reduce rainfall intrusion, and suppress radon-222 emanation. The temporary cover would also provide time for settlement in the foundation and within the cell to occur. The effects of any settlement would be repaired when the temporary cover was removed and the permanent cover installed.

The north berm of the cell would be built last, after the final waste volume figures were determined and the ultimate dimensions of the disposal cell fixed. The temporary cell cover would be replaced at this time by the permanent cell cover. The permanent cover would be constructed over the entire cell one layer at a time, in accordance with the cover design. Details of the cover design are described in Appendix B, Section B.2. After the outermost layer of the disposal cell was in place, the disposal cell area would be graded, contoured, and seeded to establish a grassy covering.

During cell construction, storm water drainage would be controlled by a combination of berms, swales, and detention ponds designed to minimize runoff of potentially contaminated materials. Storm water runoff from areas containing wastes would be directed to detention ponds to permit sedimentation and any necessary treatment prior to release to the city wastewater system.

After cell construction was completed, all storm water runoff from the cell would be clean and would be directed to the permanent detention pond. The pond would be dry under normal conditions and designed to accommodate

extreme rainfall events. An additional permanent detention pond for runoff from the reclaimed and regraded Factory Site would be constructed at the south end of the Factory Site. This pond would be designed for sediment control and flood abatement in accordance with the city of West Chicago Pollution Control Ordinance.

3.2.2 Postclosure Maintenance, Monitoring, and Surveillance

Postclosure maintenance, monitoring, and surveillance at the disposal area in West Chicago, including those activities described in Section 3.1.4, would be most intense over the first 5 years following completion of the cell, would be reduced over the next 5-year period, and then would be substantially curtailed after 10 years. The schedule would be tailored to the maturation of the cell and its vegetative cover. The government agency retaining ultimate custody of the disposal site would conduct long-term site surveillance (see 10 CFR Part 40, Appendix A, Criterion 12).

The vegetative cover would be routinely inspected to determine the need for maintenance. Similarly, inspectors would check the condition of the cell and site water-control system, access-control system, and the various monitoring systems.

Periodic maintenance of the vegetative cover would be required over the early years following cell completion until the vegetation was adequately established. Although the cell would be designed to preserve the long-term isolation of the wastes without active maintenance, some maintenance of the cell or of the water-control system might be required in the early years until the cell stabilized and the vegetative cover matured. Maintenance would be performed on any parts of the cell that were observed to require repair during the periodic inspections.

3.3 ALTERNATIVE A - DEEP-TRENCH DISPOSAL AT AN ACTIVE SURFACE COAL MINE

For Alternative A, the radioactive wastes generated from the excavation, demolition, and treatment operations at the West Chicago site (Section 3.1.1) would be transported to Midland Coal Company's Rapatee Mine in northeastern Fulton County (Figure 1.1). The reasons for selecting the Rapatee Mine as opposed to other active surface coal mines in Illinois are presented in Appendix A, Section A.3.

At the Rapatee Mine, conventional area-type surface mining procedures are being conducted to remove the Springfield No. 5 and Herrin No. 6 coal seams. The mine opened in 1976 and is expected to remain operational until about 2005, depending on the coal market and the ability of the company to obtain new sales contracts. During mining operations, the upper soil horizons are

removed first and stockpiled. Next, 5 to 8 m (16 to 26 ft) of unconsolidated glacial till materials are removed by pan scrapers and hauled to graded rock spoil areas (Figure 3.3). The underlying 10 to 15 m (33 to 48 ft) of consolidated rock is then drilled, blasted, and moved by dragline from the highwall side of the pit to the opposite spoil side. The spoil ridges are rough-graded so that pan scrapers can bring till materials over from the next strip to be mined. Once grading of the unconsolidated glacial materials is completed, the stockpiled soil material is reapplied (Figure. 3.3).

The overburden materials are removed in long narrow strips. A typical pit may be 30 m (100 ft) wide and 980 m (3,200 ft) long at the Rapatee Mine. As the coal is exposed, it is removed by a shovel. The dragline and shovel work back and forth in successive parallel cuts, which results in area-type mining. When a major road, railroad, permit boundary, or other important land feature (e.g., building) is reached, the operation is typically moved over to another area for the opening of a new cut. The final cut at the edge of a mining area is usually filled in with spoil materials pushed back into the pit or is left open so that a final-pit lake can form.

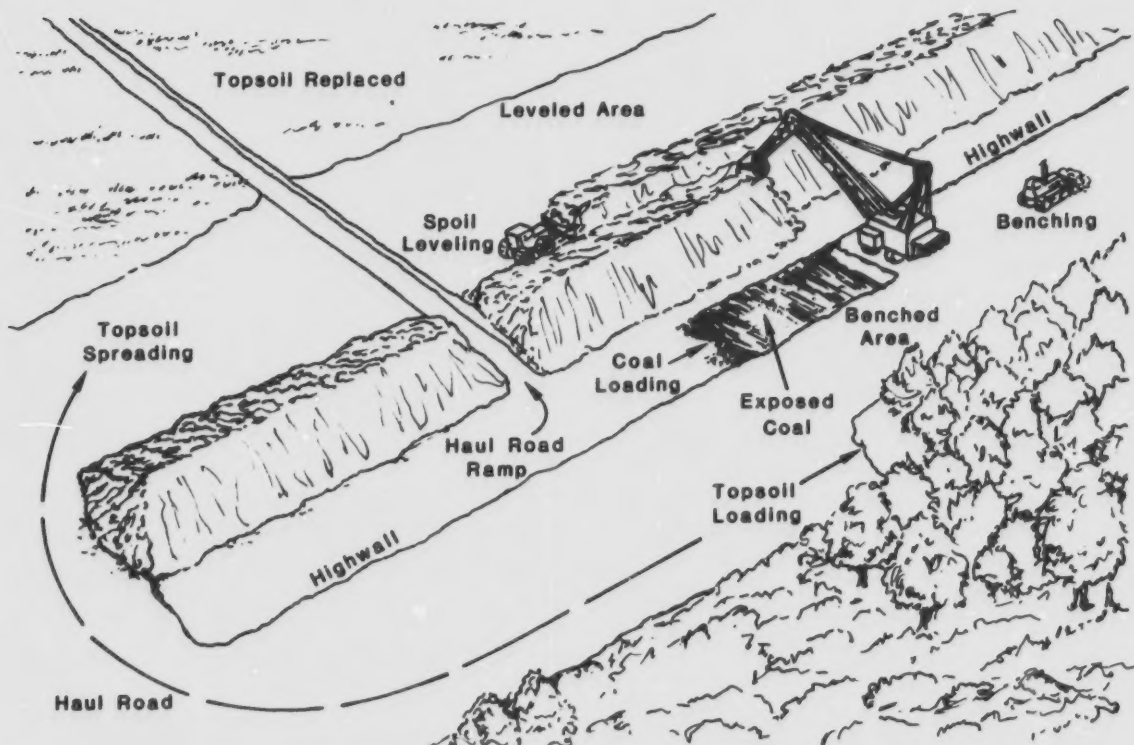


Figure 3.3. Diagram of Area-Type Surface Coal Mining Procedures.

Source: Modified from Chironis (1978).

The disposal plan for Alternative A is to use an unfilled final cut at the edge of a mined parcel of land as a deep-trench disposal cell. Because a mine pit is up to 25 m (82 ft) deep and the depth to the water table is generally less than 5 m (16 ft), deep-trench disposal would result in slow groundwater inflow and eventual saturation of the wastes over a very long period of time.

The pit highwall, which would form one side of the disposal cell, is composed of in situ geologic materials (i.e., shales, thin limestones, and glacial till) that have been slightly disturbed by blasting and removal of lateral support during the mining operations. The pit floor is composed of the No. 5 underclay, which is about 1.5 m (4.9 ft) thick and has very low hydraulic conductivity (see Appendix A, Section A.3). The spoil side of the pit initially would have a high ridge of spoil materials left by the dragline.

3.3.1 Site Preparation

The main advantage of using a surface mine disposal site is the availability of a large pit, which would save a major excavation expense (see Appendix A, Section A.3). Some earth-moving work would be necessary, however, to prepare the disposal cell prior to waste emplacement. The highwall and pit floor are composed of low-permeability geologic materials (Figure 3.4), but the side of the pit opposite the highwall is composed of spoil materials that would have to be graded and compacted to increase stability and reduce permeability. Glacial till materials (silty clay) would be stockpiled on the highwall side next to the pit by pan scrapers during the active phase of mining. During site preparation, the stockpiled till would be brought into the pit, placed in lifts against the toe of the spoil materials, and compacted. These lifts would be about 1 m (3.3 ft) thick and 6.1 m (20 ft) wide. This compacted embankment would form a low-permeability sidewall for the disposal cell. Existing haul ramps from the mining operation would be used for access into and out of the mine pit.

3.3.2 Packaging, Transport, Receipt, and Emplacement of Wastes

The wastes would be packaged according to U.S. Department of Transportation regulations (49 CFR Part 173). The low-specific-activity materials would be packaged in strong, tight containers; other wastes would be shipped in bulk. After receipt of the wastes at the surface mine site, the wastes would be hauled directly to the disposal cell. Wastes would be emplaced in the mine by hauling the wastes in a truck onto the floor of the disposal cell and dumping the contents onto the floor. The wastes, except for those in containers, would be built up in layers (e.g., 2-m lifts) and compacted.

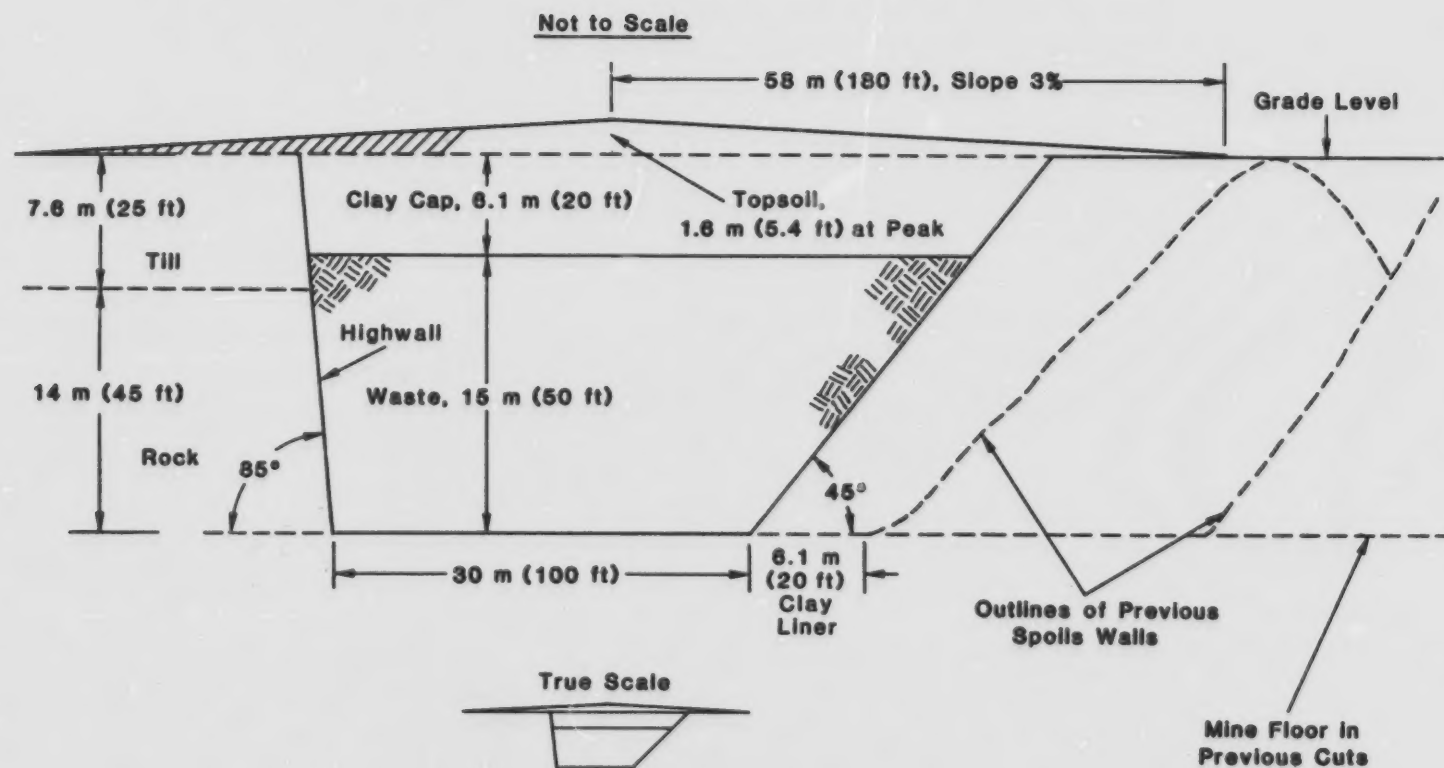


Figure 3.4. Cross Section of Deep Trench, Using the Final-Cut Pit of a Surface Coal Mine.

3.3.3 Closure of Disposal Cell and Site

The upper portion (about 6 m) of the mine pit would be filled with fine-grained spoil materials and/or clayey till in 1-m lifts and compacted. Cell closure would be completed by adding a layer of topsoil, as described in Appendix B, Section B.3. The unusually great depth of wastes from the surface in this concept eliminates the need for a cap incorporating special layers to divert infiltrating precipitation or to provide barriers to burrowing animals and penetrating roots. With the addition of the outermost cover layer (topsoil), the entire area of the disposal cell would be slightly higher than the surrounding land surface (Figure 3.4) and would be contoured for surface drainage away from the disposal cell and into the permanent detention basin. After emplacement of the cover, lateral drains would be placed at the periphery of the disposal cell, and the cover would be seeded with grasses native to the area. Monitoring wells would be constructed near the disposal cell.

3.3.4 Postclosure Surveillance

Groundwater would be routinely monitored through a set of wells surrounding the disposal area to detect migration of radionuclides and to indicate the need for any mitigation or maintenance to counteract the migration. Because of the location of the wastes below the water table in Alternative A, a relatively small spacing between monitoring wells is recommended for consideration in the final design stage. Because of the remoteness of the wastes from the surface environment, however, air monitoring and subsidence monitoring would probably be less important.

3.4 ALTERNATIVE B - DEEP-TRENCH DISPOSAL AT A RECLAIMED SURFACE COAL MINE

For Alternative B, after excavation, demolition, and treatment operations at the West Chicago site (see Section 3.1.1), the wastes would be transported to the Elm surface coal mine in western Peoria County (Figure 1.1). At the Elm Mine, the Kerr-McGee wastes would be placed in a final-cut pit and covered with compacted mine spoil materials (see Figure 3.4 and Appendix B, Section B.3). The reasons for selecting this site are discussed in Appendix A, Section A.4. The Herrin No. 6 Coal was extracted at the Elm Mine by Midland Coal Company from 1970 to 1984. Since 1984, the mined land has been undergoing reclamation. Much of this mined property has been graded relatively flat, planted in grasses, and used for grazing. Around the perimeter of the mined areas are numerous final-cut lakes, which generally have steep banks and water levels about 3 to 5 m (10 to 16 ft) below the surrounding surface grade.

3.4.1 Site Preparation

A final-cut lake runs in an east-west direction along the southernmost edge of the mined area at the Elm Mine (Figure 3.5). Large graded and revegetated spoil banks are located on the north side of the pit area and on either side of the pit ramp area. The first site-preparation step would be to completely drain the lake by pumping out the water and discharging it to the north. Final-cut impoundments in Peoria, Knox, and Fulton counties are

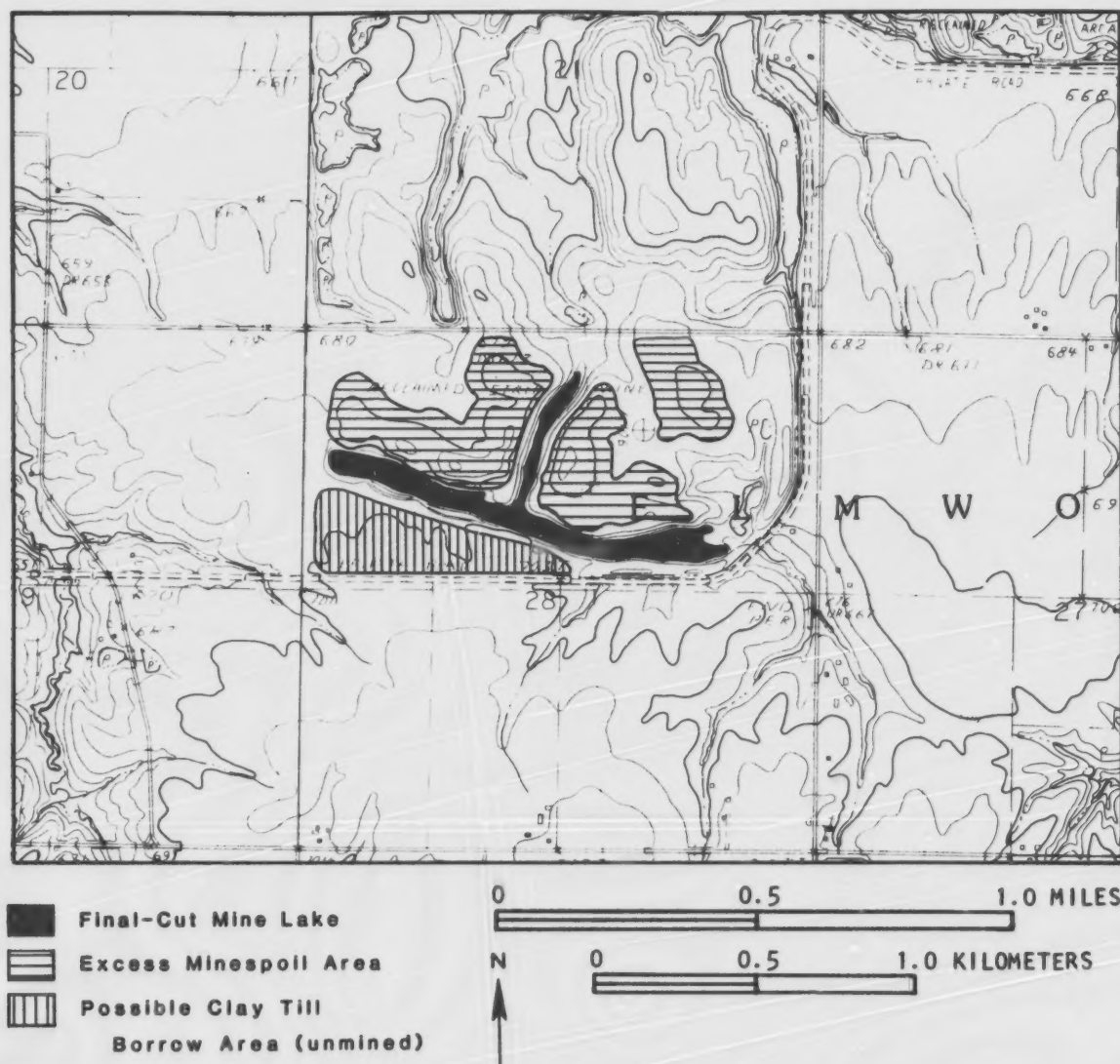


Figure 3.5. Reclaimed Surface Coal Mine (Alternative B) Disposal Area before Site Preparation.

Base Map: U.S. Geological Survey, Farmington East
7.5-Minute Quadrangle, Provisional Edition (1982).

generally alkaline and low in trace metals (e.g., iron, manganese, cadmium, lead, and copper). The water should not need treatment prior to discharge. Extra minespoil materials from spoil hills on the north side of the lake (see Figure 3.5) would be reserved for construction of the disposal cell cap.

The road access at this mine would need upgrading before construction began. One or more buildings at the mine office and coal-preparation plant might be adapted to such functions as change house, waste-receipt office, administration building, and maintenance shops. Power, water, and communications might have to be reinstalled. A security system, including fences and gates, would also be installed.

3.4.2 Packaging, Transport, Receipt, and Emplacement of Wastes

Packaging, transport, receipt, and emplacement of wastes in the reclaimed surface mine would be similar to those same activities at the active surface coal mine (see Section 3.3.2).

3.4.3 Closure of Disposal Cell and Site

Closure of the disposal cell and site would be similar to that for the active surface coal mine (see Section 3.3.3).

3.4.4 Postclosure Surveillance

Postclosure surveillance activities would also be similar to those described for the active surface coal mine (see Section 3.3.4). Subsidence, and the corresponding need for cover repair, could be checked by periodically measuring the elevation of reference monuments set into the cover.

3.5 ALTERNATIVE C - DISPOSAL AT AN UNDERGROUND COAL MINE

For Alternative C (underground coal mine), the Kerr-McGee wastes would be transported to Ziegler Coal Company's Murdock Mine in northern Douglas County in east-central Illinois (see Figure 1.1). The wastes would be transported in reusable containers via two vertical shafts or slope entrances down into the coal mine, 80 m (260 ft) below the surface, and placed in two panels of the mine workings. A plan view of the disposal situation is shown in Figure 3.6; a cross section is shown in Figure 3.7. Further details about the mine site and reasons for its selection are given in Section 4.6.4 and Appendix A, Section A.5. Further details about emplacement of the wastes in the mine are presented in Appendix B, Section B.4.

Bulkhead seals would be constructed across all entrances to the disposal panels, equipment would be removed from the mine, and the two shafts and slope

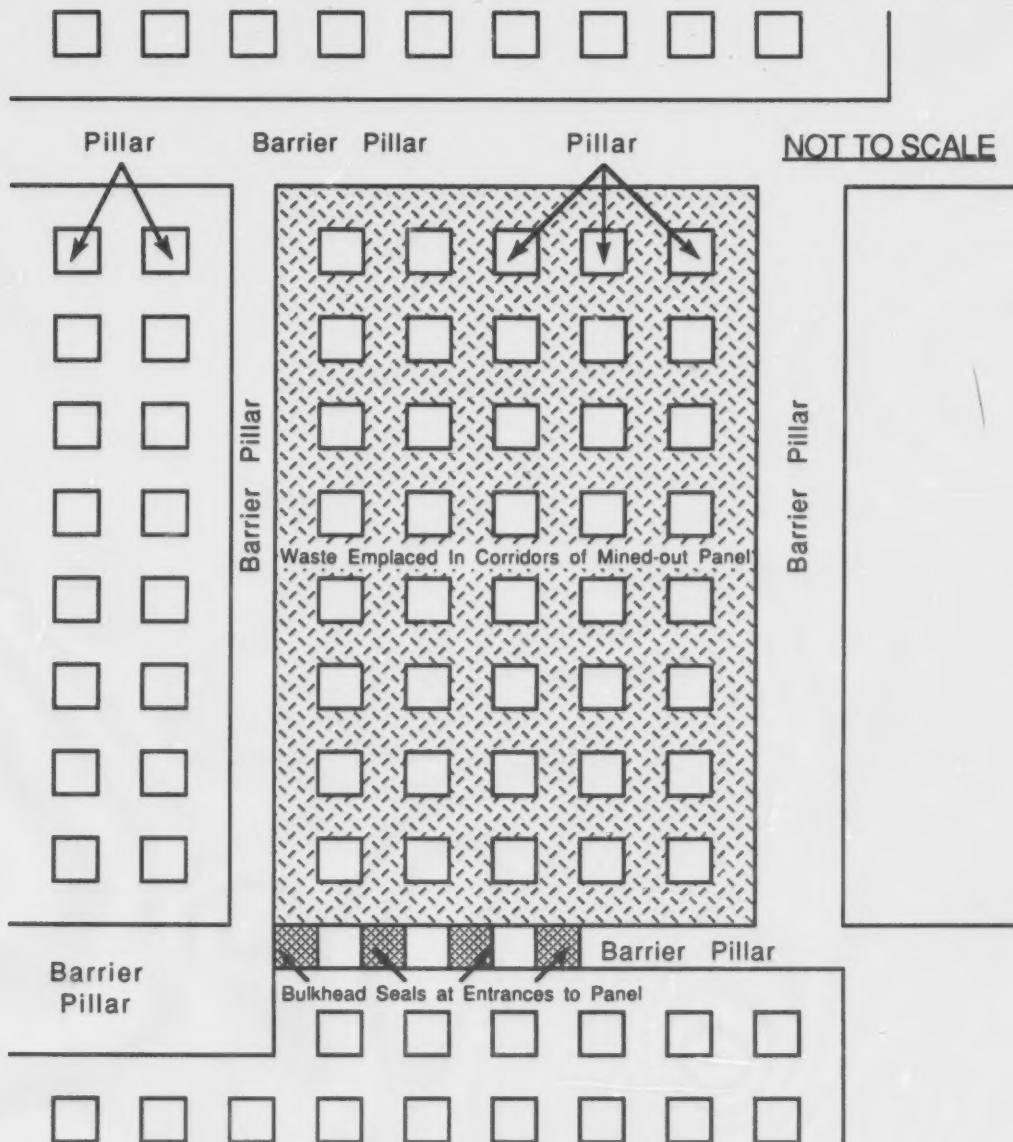


Figure 3.6. Underground Containment System (Coal Mine): Plan View.

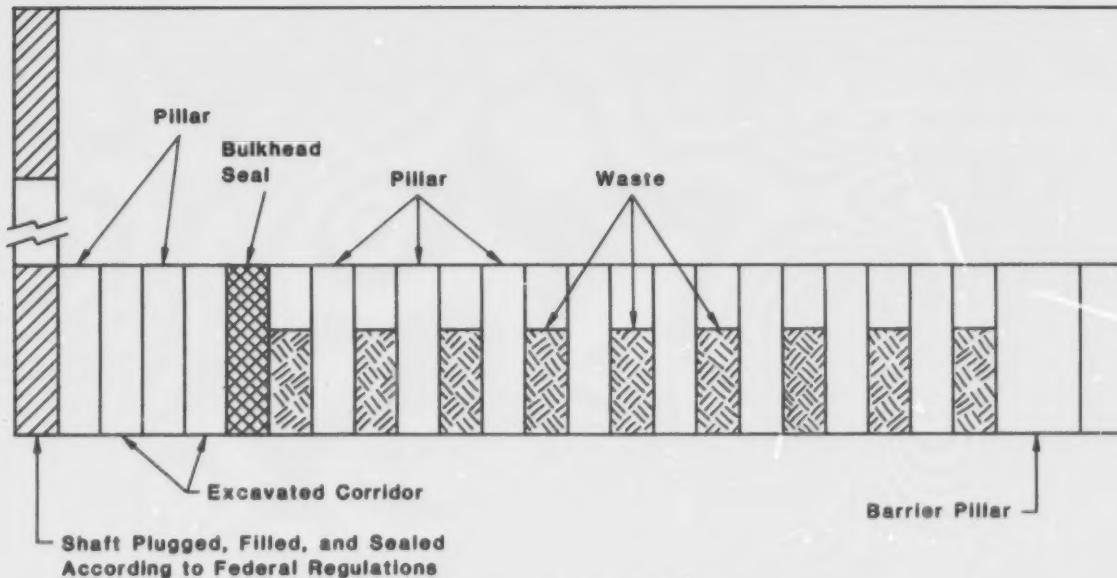
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Figure 3.7. Underground Containment System (Coal Mine): Cross Section.

entrances to the mine would be plugged and sealed according to federal and state regulations (e.g., see 30 CFR Part 817).

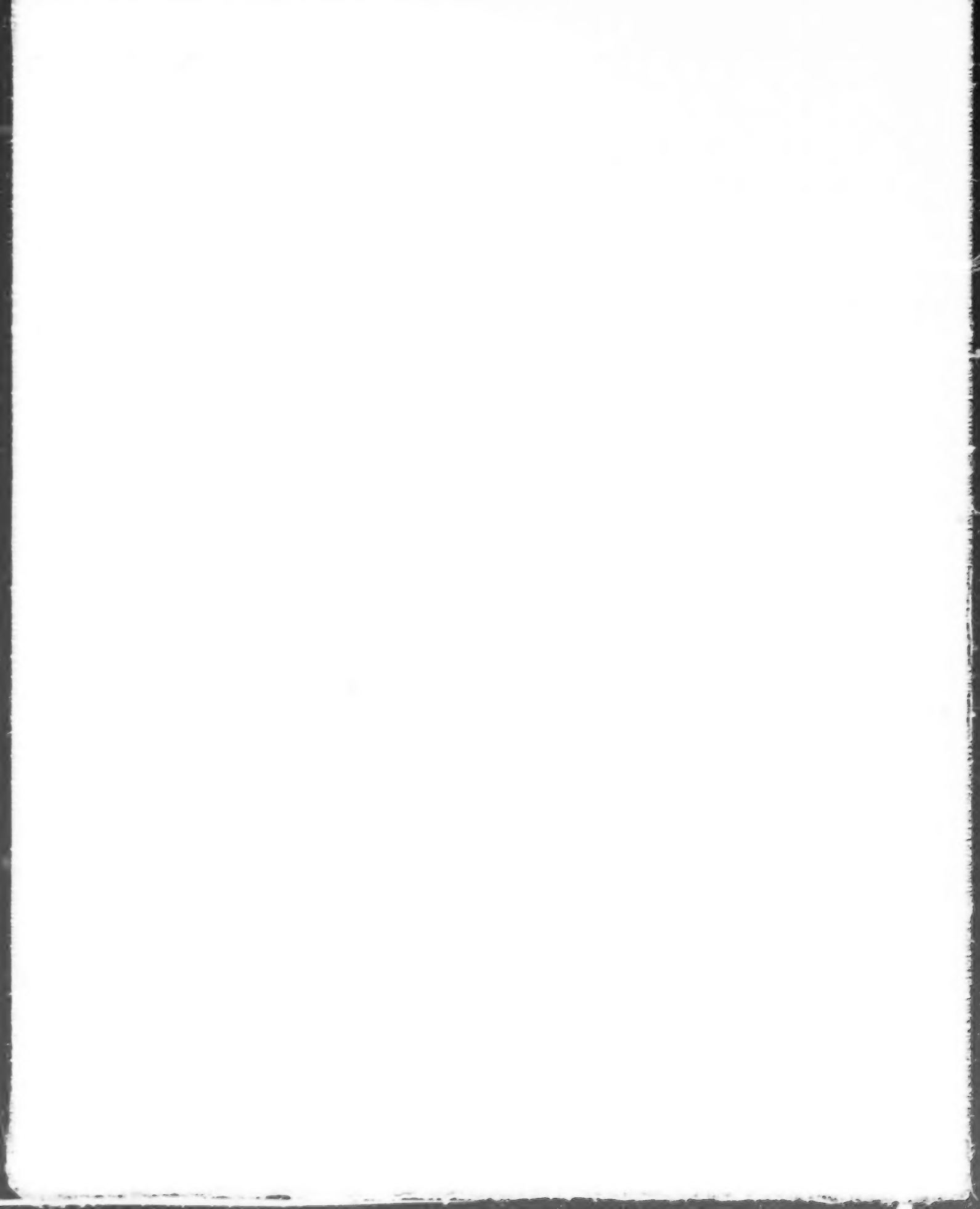
3.5.1 Site Preparation

Little preparation would be required for the underground coal mine alternative; wastes would be emplaced into cavities previously created during coal extraction. Because waste-disposal operations would begin soon after the completion of coal mining, power lines, communication lines, and ventilation equipment should all be operational. Disposal cell construction, an important activity in each of the other alternatives, would be unnecessary for this alternative. In addition, the roads, buildings, rail line, and other surface facilities would need only minor modifications for disposal operations.

Site preparation would consist mainly of (1) installation of facilities for the crew that would receive and emplace the wastes, (2) reinforcement of roof rock in working areas to ensure safety during the emplacement period, (3) possible purchase of some vehicles for waste emplacement, (4) installation of facilities for washing down trucks and other vehicles, (5) installation of a monitoring station for men and equipment, and (6) construction of a settling pond for water pumped out of the mine.

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Some amount of seepage is always present in deep underground mines. This water would have to be pumped out during waste emplacement activities, but the only treatment that might be required prior to discharge would be a settling pond to remove suspended solids.

3.5.2 Packaging, Transport, Receipt, and Emplacement of Wastes

Wastes would be transported to the underground mine by truck (Section 5.9.2.2). Transportation of borrow material for a bottom liner, a cap, and other components used in the cover of the other alternatives would be unnecessary for disposal in an underground coal mine. Transport vehicles would require a water-treatment system at the underground coal mine for sedimentation and for removal of radionuclides, if necessary, from wastewater generated in vehicle washdown. Although there would be no need to create drainage systems to handle runoff of precipitation from the disposal cell, it would be necessary to stockpile wastes temporarily and to collect and treat any runoff from the stockpile. For binned (packaged) wastes, emplacement in an underground mine would require equipment for off-loading, handling, and stacking of packages. For bulk wastes, the wastes would be transported down the mine in reusable containers, and emplacement would be carried out by rubber-tired haulage vehicles and forklifts.

3.5.3 Closure of Disposal Cell and Site

Closure of the underground mine disposal cell would entail sealing the panels into which the wastes were placed, using typical panel-sealing techniques for coal mines. The entrances to the panels would be closed by a wall of cement blocks and/or poured concrete (i.e., bulkhead seals), and the shafts and slope entrance to the mine would then be filled with earthen materials and sealed with concrete plugs according to state and federal regulations (e.g., see 30 CFR Part 817). The functions of a cover (e.g., radon barrier, intruder barrier, drain, and erosion retardant) are presumed to be unnecessary in such a disposal cell. The subsurface bulkhead seals and mine shaft plugs would be adequate intruder barriers, and the distance to the surface would be sufficient so that radon escaping from the wastes would have decayed before reaching the surface environment.

3.5.4 Postclosure Surveillance

Postclosure activities would consist of controlling access to the disposal area and monitoring deep wells and nearby streams. Surveys and visual inspections of the land surface would be done on a regular basis to monitor for subsidence of rock above the disposal panels; although subsidence would be highly unlikely, monitoring should be conducted to verify stability of the disposal cell.

3.6 ALTERNATIVE D - PARTIAL BURIAL ON A FARMLAND SITE

For Alternative D (partial burial on farmland), the Kerr-McGee wastes would be transported to a farming area in north-central Livingston County in northeastern Illinois (Figure 1.1). The reasons for selecting this site are discussed in Appendix A, Section A.6. In this alternative, a portion of the wastes would lie below grade (Figure 3.8).

3.6.1 Site Preparation

The area for the disposal cell would be prepared by excavating a square area, about 340 m (1,100 ft) on a side, to a depth of 1.2 m (4 ft). Excess till would be stockpiled and used later for construction of the disposal cell cover. The floor of the cell would be prepared by compacting the underlying silty clay glacial till material and then laying a network of drainpipes and the sand filter-drain as described for the above-grade disposal cell in Appendix B, Section B.2; construction of a berm would not be required. The need for lateral confinement in the partial burial alternative is less because the waste pile would have less height and would be spread over a larger area. The waste pile would be laterally confined by the wall of the excavation made for partial burial.

3.6.2 Packaging, Transport, Receipt, and Emplacement of Wastes

Transportation of wastes to the farmland site would be facilitated by the nearness of the site to Interstate 55. Waste packaging, receipt, handling, and emplacement techniques would be similar to those described for the deep trench (see Section 3.3.2).

3.6.3 Closure of Disposal Cell and Site

After emplacement of the wastes was completed, the cell would be closed with a layered cover similar to that used for above-grade disposal in the Proposed Action, i.e., a clay cap over the wastes and successive layers of sand and gravel, low-permeability soil, cobbles, and topsoil. The method of construction would be similar to that described in Appendix B, Section B.2.

3.6.4 Postclosure Surveillance

Monitoring of soil, water, and air -- as well as inspection and maintenance of the disposal cell after closure -- would be similar to that for the above-grade disposal cell (see Section 3.2.2).

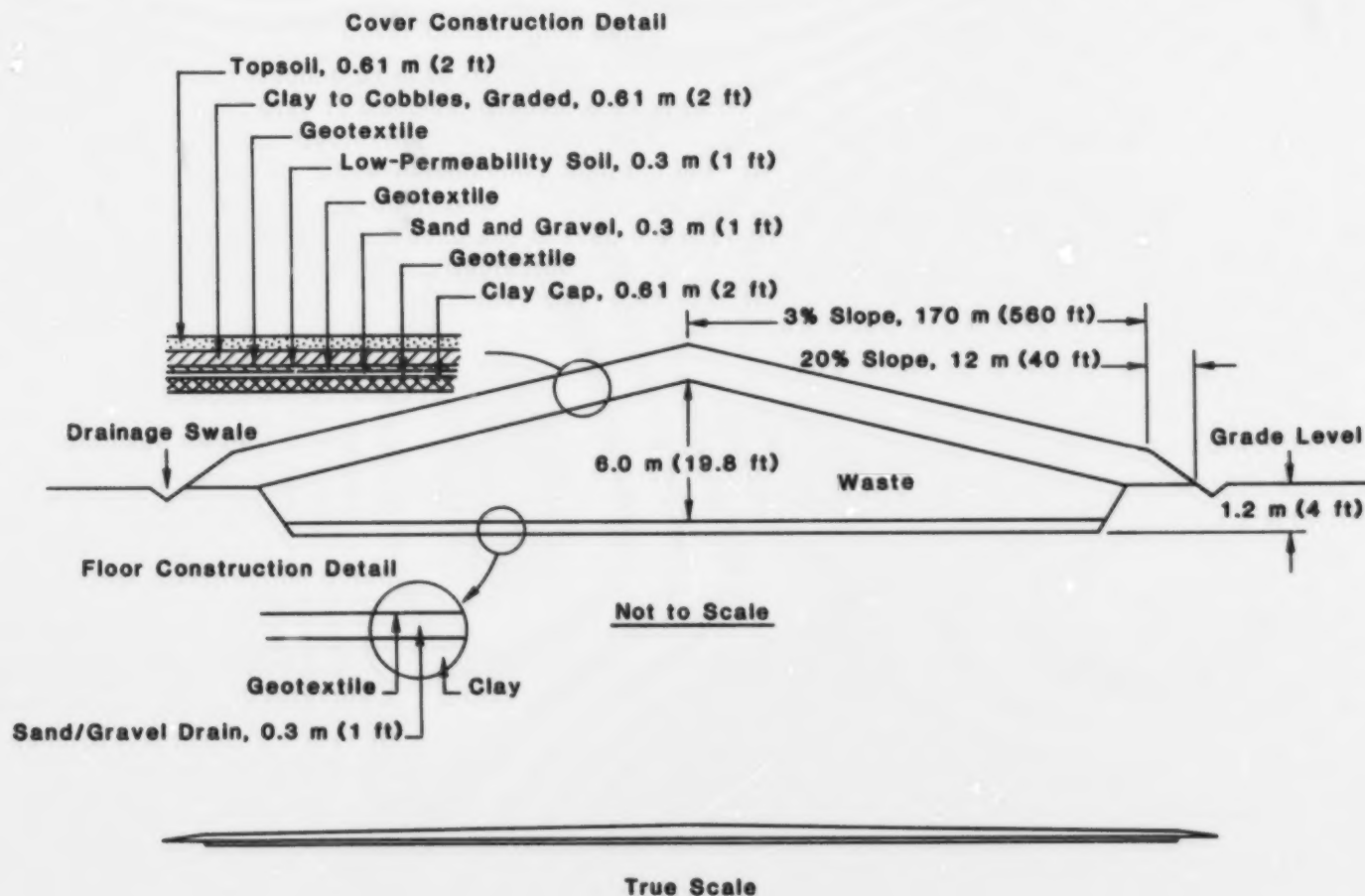


Figure 3.8. Cross Section of Partial-Burial Disposal Cell.

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3.7 WORK FORCE REQUIREMENTS

Estimates of the work force requirements for the Proposed Action and its alternatives are given in Table 3.1. The requirements (in person-years) for the action period are divided into the work force required for transportation and that required for the other activities. The estimates were derived from monetary cost estimates for the Proposed Action and alternatives by analyzing what fractions of the costs could be considered as labor costs. Details are given in Appendix F. A range of $\pm 40\%$ is also given to be consistent with the $\pm 40\%$ range given for the cost estimates in Chapter 8, Table 8.2. Work force requirements for the 1,000-year maintenance, monitoring, and surveillance period are given as annual requirements for the two 5-year periods and the final 990 years. The total requirements and a $\pm 70\%$ range (Table 8.2) are also given for the 1,000-year period. Details on derivation of the values are given in Appendix F.

The Proposed Action would have the smallest total work force requirement (104 person-years) because no off-site transportation of wastes would be involved. Alternatives A, B, and D would have a similar total requirement, about 220 person-years. Alternative D would have the smallest work force requirement for transportation, 71 person-years, because the transport distance is the shortest among the off-site alternatives. Work force requirements (excluding transportation) for the remedial activities would be largest for Alternative D, 150 person-years, primarily because of the large amount of work needed to build the extensive cell cover.

The total work force requirements would be larger for the 1,000-year period than for the action period for the Proposed Action and Alternatives A, B, and D. Requirements would be lowest for Alternative C because the wastes would be buried deep underground. More details are given in Appendix F.

Table 3.1. Summary of Estimated Work Force Requirements for the Different Alternatives^a

Activity	Work Force (person-years) ^b				
	Proposed Action	Alternative A	Alternative B	Alternative C	Alternative D
<u>Action Period</u>					
Transportation	0	118	108	106	71
Other activities	104	106	115	95	149
TOTAL, Action Period	104	224	223	201	220
Range	60-140	130-310	130-310	120-280	130-310
<u>Maintenance, Monitoring, and Surveillance (MMS)</u>					
Annual (person-years/year)					
First 5 years	2	1	1	0.5	2
Next 5 years	1	0.5	0.5	0.25	1
Next 990 years	0.5	0.25	0.25	0.12	0.5
TOTAL, MMS (person-years)	510	260	260	130	510
Range ^c	150-870	78-440	78-440	34-220	150-870

^a Source: Appendix F. Values rounded to two significant figures. Totals do not add because of roundoff errors.

^b One person-year equals 2,000 person-hours.

^c Range was calculated as $\pm 70\%$ of the total to be consistent with the cost range in Table 8.2.

3.8 REFERENCES

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Kerr-McGee Chemical Corporation. 1981. The Applicant's Preferred Remedial Action Plan. Supplement to Stabilization Plan: License STA-583. Attachment to letter from W.J. Shelley (Vice-President, Nuclear Licensing and Regulations, Kerr-McGee Corporation, Oklahoma City, Okla.) to W.A. Nixon (Uranium Process Licensing Section, U.S. Nuclear Regulatory Commission, Washington, D.C.), December 11, 1981.

Kerr-McGee Chemical Corporation. 1986. West Chicago Project Engineering Study. Volume IV - Foundation; Volume IX - Construction. U.S. Nuclear Regulatory Commission, License No. STA-583. Information Transmittal, April 1986. 20 binders.

4. AFFECTED ENVIRONMENTS

4.1 LOCATION AND TOPOGRAPHY

4.1.1 West Chicago Site (Proposed Action)

The Kerr-McGee Rare Earths Facility is located in a residential-industrial area on the southwest side of West Chicago in DuPage County, (Figure 4.1), about 50 km (30 mi) west of the city of Chicago in northeastern Illinois. The site is situated in SE1/4, Section 9, and NE1/4, Section 16, T39N, R9E.

Northeastern Illinois is characterized by glacial morainic topography, which includes a variety of elongated low hills, mounds, basins, and valleys. West Chicago lies in between two glacial moraines that trend north to south; the West Chicago moraine lies directly to the east of the city of West Chicago and the Minooka moraine lies approximately 5 km (3 mi) west of the site along the western boundary of DuPage County (Willman and Frye 1970). In between these two end moraines lies flat to gently rolling land, with a general slope toward the south. The area has local relief of about 20 m (65 ft) and is drained by the southward-flowing West Branch DuPage River and its tributary Kress Creek (Figure 4.1). At the Kerr-McGee West Chicago site, the land surface elevation* ranges from approximately 232 m (760 ft) at the north end to 223 m (730 ft) at the south end, with a southwesterly slope toward Kress Creek. Local slopes steepen near the West Branch DuPage River and Kress Creek, where the elevation is approximately 213 m (700 ft). The average southward slope of the natural land surface at the Kerr-McGee site is about 1%.

The original site topography has been extensively modified over the years by fill material, two borrow pits, five excavated ponds, dikes, and an ore residue waste (tailings) pile (Figure 4.2). Drawings presented by Kerr-McGee (1986--Vols. II, III, and IX) show that the one residue waste pile has a maximum elevation of about 233 m (765 ft). The bottoms of ponds 1-5 (excluding the waste sludge materials) were excavated down to elevations of about 221, 221, 225, 221, and 223 m, respectively. All of the ponds except pond 3 were excavated into the E sand and gravel deposit below the F stratum and below the water table. Waste sludges now fill each of these ponds to various depths; the maximum depth of wastes is about 8 m (25 ft) in pond 1.

*All elevations in this document are in meters above mean sea level.

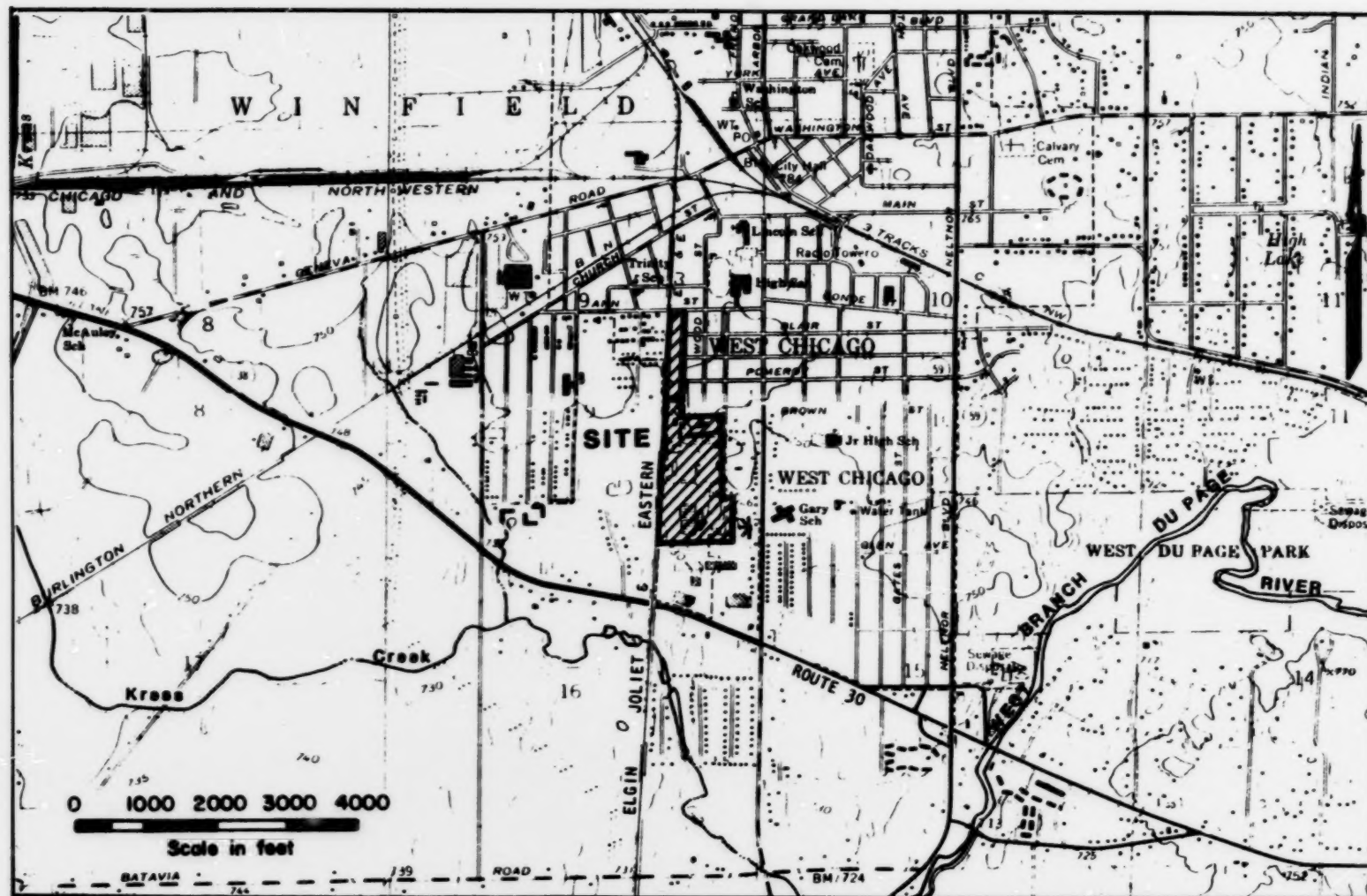


Figure 4.1. Local Area around the Kerr-McGee Site, West Chicago, Illinois.

Source: Modified from Kerr-McGee (1986--Vol. II).

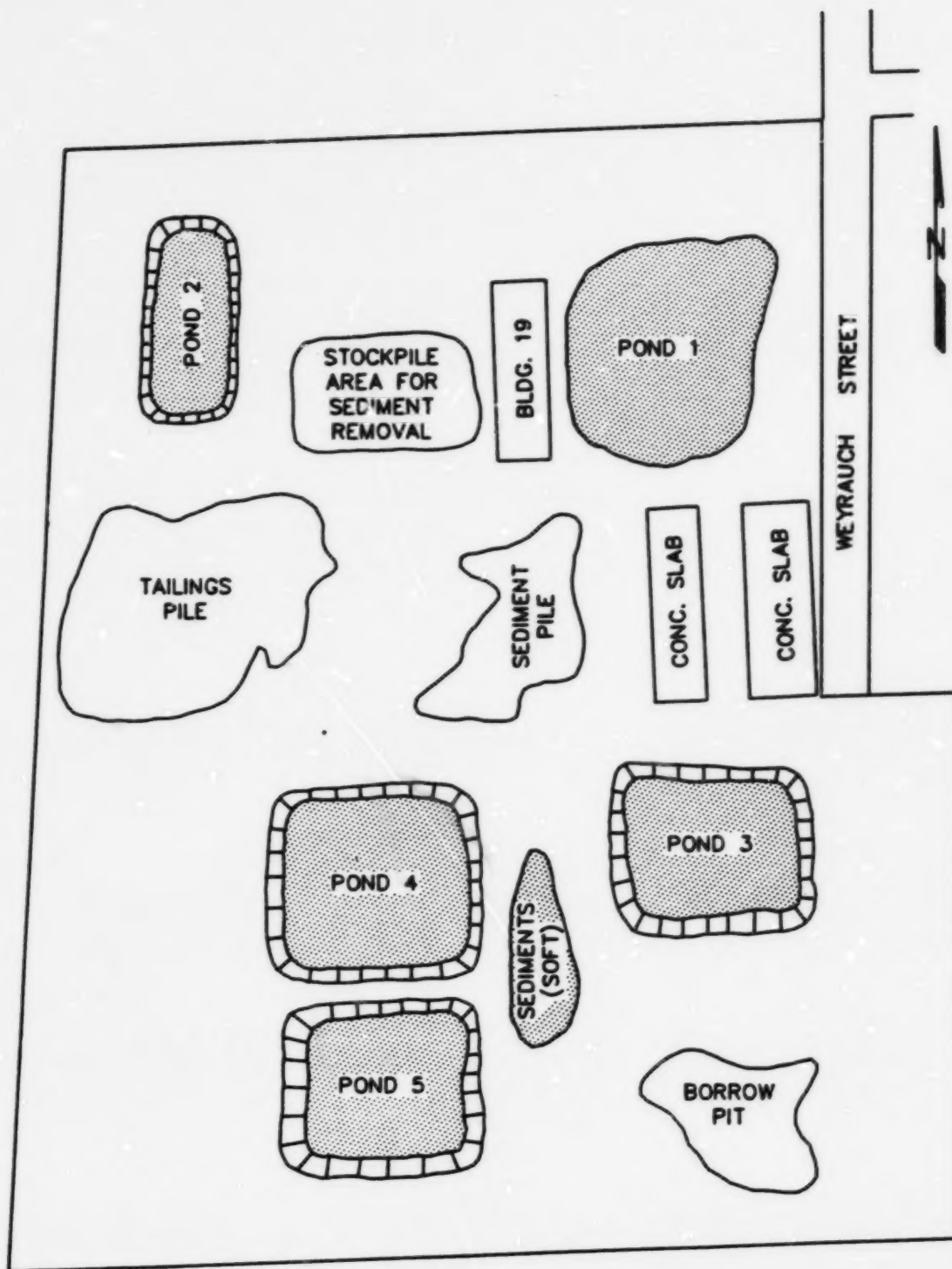


Figure 4.2. Disposal Site Area on the Kerr-McGee Site.

Source: Kerr-McGee (1986--Vol. IX, Fig. 9-6).

4.1.2 Active Surface Coal Mine (Alternative A)

The Rapatee Mine, chosen as Alternative A, is located in northeastern Fulton County (T8N, R3E) (Figure 4.3). The nearest town is Rapatee in Knox County, about 2 km (1 mi) to the northwest. Other nearby towns include Middle Grove, Fairview, and Farmington, which are about 2, 7, and 10 km (1, 4, and 6 mi) distant, respectively (Figure 4.3).

The surface coal mine site is located on a relatively flat upland, which has a surface elevation that ranges from about 205 to 220 m (670 to 720 ft). Regionally, this area is part of the Galesburg Plain physiographic province of Illinois (Leighton et al. 1948). Much of the mine permit area is located in the headwater area of Swegle Creek, a small stream that flows westward and is a tributary to the Spoon River (Figure 4.3). The north side of the mine permit area is bounded by the incised valley of Littlers Creek, which has an

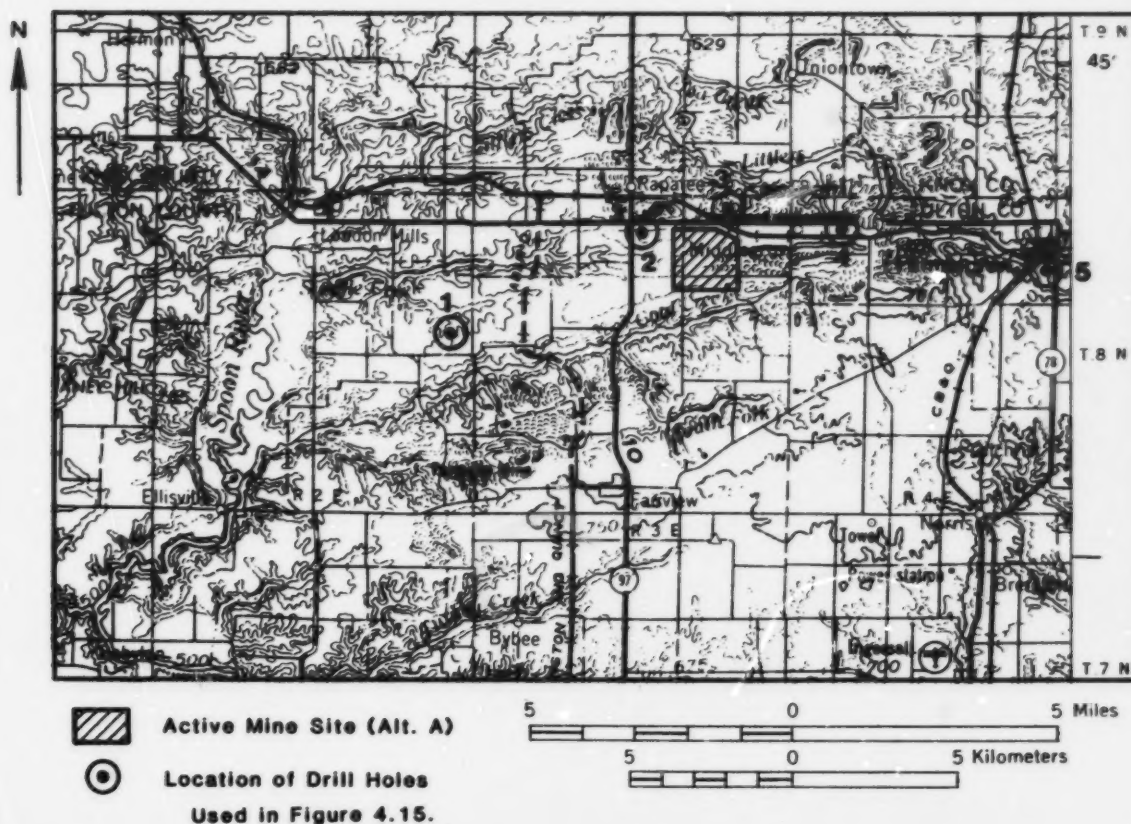


Figure 4.3. Location and Physiography of the Active Surface Coal Mine Site.

Base Map: U.S. Geological Survey, Burlington (Iowa, Ill., Mo.) 1° x 2° topographic map, 1967 revision.

elevation of about 176 m (580 ft) north of the mine. Littlers Creek flows northwest and west and also joins the Spoon River. The south side of the mine permit area is bounded by the Coal Creek valley, which has an approximate elevation of 192 m (630 ft) due south of the mining area. Coal Creek flows west-southwest and enters the Spoon River near Ellisville.

The land area on the east side of the active mine has been strip mined in the past and was never graded back to original contour, so ridges of cast overburden are interspersed with pit lakes. The surface drainage patterns of this area are quite irregular because many of the lakes are located in drainage basins having no surface outlets. The surface water that does drain out of this previously mined area flows either northward into Littlers Creek or southward into Coal Creek.

4.1.3. Reclaimed Surface Coal Mine (Alternative B)

The Elm Mine, chosen as Alternative B, is a former surface coal mine in western Peoria County that is now reclaimed. The mined areas are patches that lie in an east-west trend through T9N, R5E, and smaller areas in T9N, R6E (Figure 4.4). The older Edwards surface coal mine lies directly to the east. Most of the Elm Mine and the Edwards Mine have been graded to gently rolling topography and revegetated to pasture. Many pits were left to fill with water, so pit lakes are now common throughout the area. One or more of these lakes are used by sportsmen's clubs for boating, fishing, and swimming.

The mine area lies on a flat upland that ranges in elevation from about 200 to 235 m (650 to 770 ft). The upland area is bounded on the west and north by the deeply incised valley of the West Fork of Kickapoo Creek, which has an elevation ranging from 165 to 180 m (540 to 590 ft) north of the Elm Mine area. This stream flows from northwest to southeast and enters the Illinois River on the south side of Peoria. Several small streams (e.g., Warsaw Run, Nixon Run, and Clark Branch) flow northward from the mined areas and enter the West Fork of Kickapoo Creek. The Elm Mine lies on the northern half of the upland area; surface drainage is therefore northward into the West Fork of Kickapoo Creek. The south and southeast sides of the upland are drained by several southward flowing streams, including the East Branch and Middle Branch of Copperas Creek, Tiber Creek, Largent Creek, and several smaller creeks (Figure 4.4).

Several towns are located in the areas surrounding the mine site. The tract of mined land that appears most promising as a candidate site is located in Section 28, T9N, R5E (see Appendix A, Section A.4). The town of Elmwood is 5.6 km (3.5 mi) northwest and the town of Farmington is 6.4 km (4 mi) southwest of this tract. The smaller towns of Cramer and Trivoli are located about

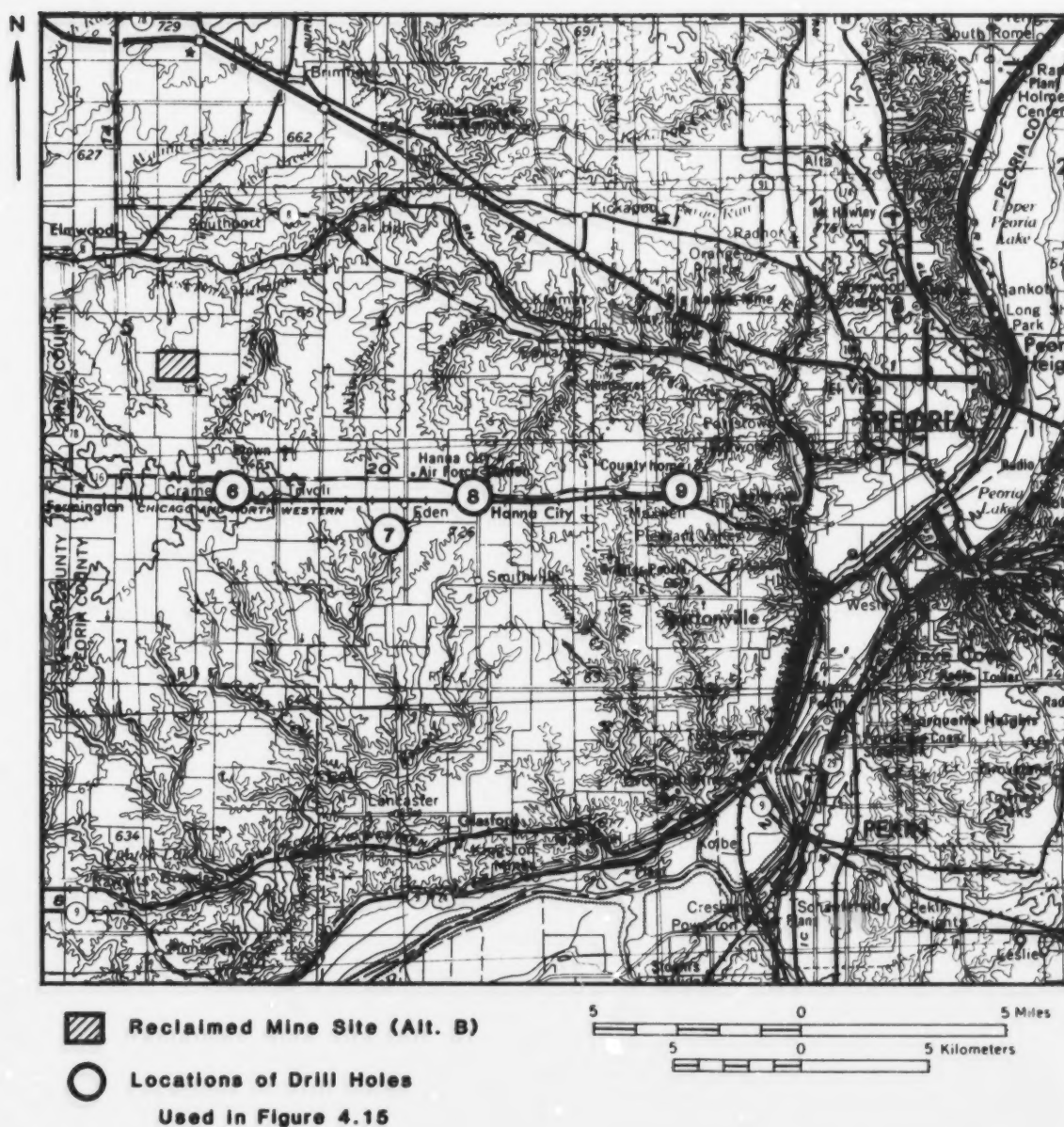


Figure 4.4. Physiography of the Reclaimed Surface Coal Mine Site and Surrounding Area.

Base Map: U.S. Geological Survey, Peoria (Ill.)
1° x 2° topographic map, revised 1971.

4.8 and 6.4 km (3 and 4 mi) south and southeast of the tract, respectively. Hanna City is farther east and is located closer to the Edwards area (Figure 4.4).

4.1.4 Underground Coal Mine (Alternative C)

The Murdock and No. 5 underground coal mines are located directly adjacent to each other in the northeast corner of Douglas County in eastern Illinois (T15N and T16N, R10E). The underground mine workings surround the town of Murdock on the north, east, and south sides, but do not extend under the town itself (Figure 4.5). Hugo, Camargo, Fairland, Villa Grove, Hindsboro, and Oakland are other nearby towns that are located 8 to 23 km (5 to 14 mi) from the shaft entrances of the Murdock Mine.

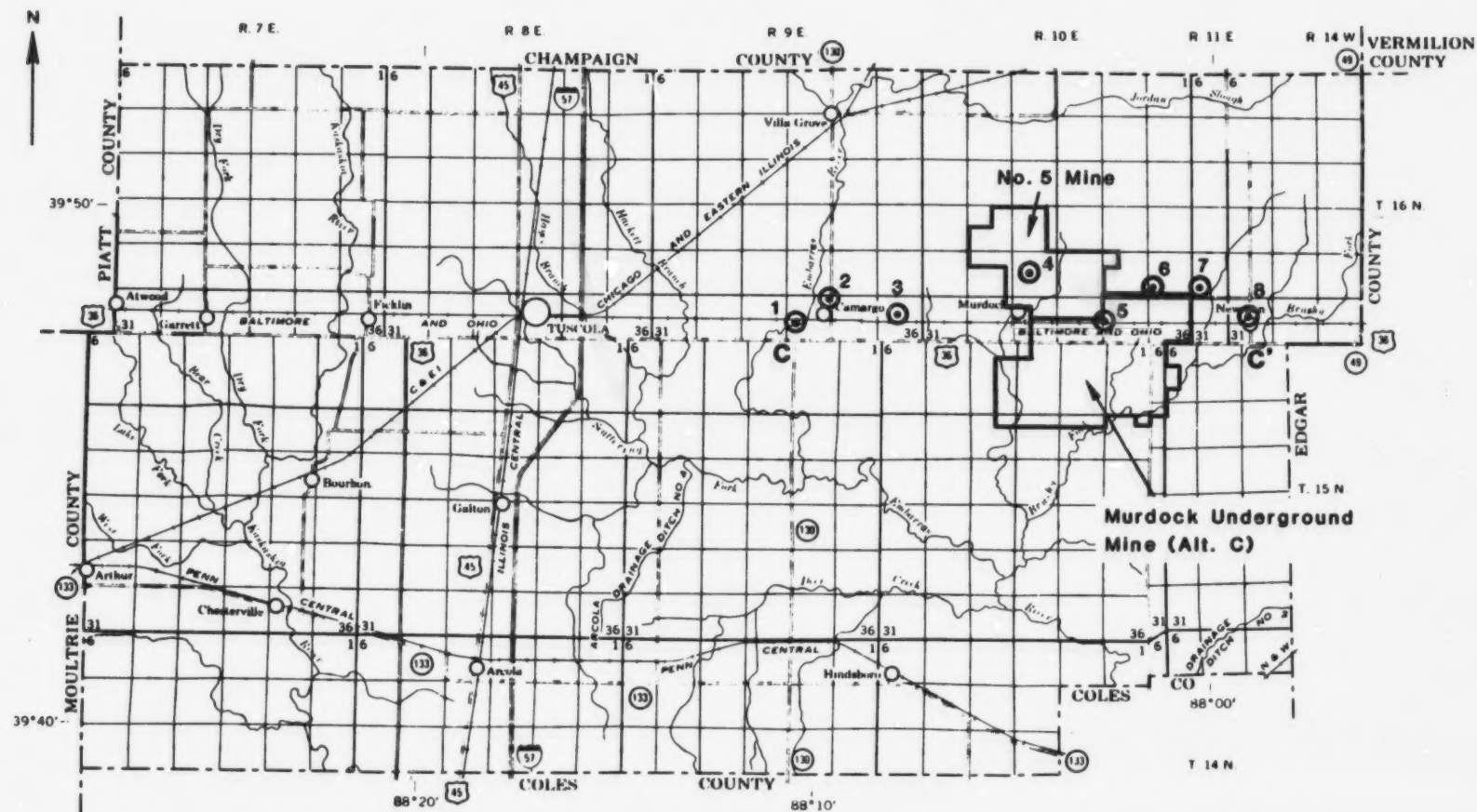
This area is part of the Bloomington Ridged Plain physiographic province of Illinois (Leighton et al. 1948). The north end of the mine complex underlies the West Ridge glacial moraine, the highest geomorphic feature in the vicinity of the mines (surface elevation ranges from 210 to 220 m). The entire land surface overlying the mine complex drains southward into several tributaries of Brushy Fork, which flows southward into the Embarras River. The mine complex underlies various portions of Brushy Creek and its tributaries (Figure 4.5).

Most of the land area overlying these two underground mines was once covered by glacial Lake Douglas and had extensive lakebed silts and clays deposited up to an elevation of about 194 to 195 m (635 to 640 ft) (see Section 4.6.4). As a result, the land area is very flat south of the West Ridge moraine. On the north side of the West Ridge moraine, the land surface drains northward into Jordan Slough, which flows westward and enters the Embarras River at Villa Grove.

4.1.5 Farmland Site (Alternative D)

The farmland site, chosen as Alternative D, is located in the north-central portion of Livingston County in northeastern Illinois (SE1/4, T30N, R5E). It is situated on the Ransom moraine of the Marseilles Morainic System (Figure 4.6). The base elevation of the glacial moraine is at approximately 201 m (660 ft) and ranges up to slightly greater than 232 m (760 ft) in this township (T30N, R5E). The site is a relatively flat upland area on the crest of the moraine, ranging in elevation from 219 to 226 m (720 to 740 ft). With only 6 m (20 ft) of topographic relief in this large area, the slopes are very gentle.

The moraine trends northwest-southeast in this part of Livingston County. The northeast side of the moraine is part of the Mazon River



⊙ Locations of Drill Holes Used in Figure 4.22

Scale 1:190,080
1 0 1 2 3 4 Miles

Figure 4.5. Physiography of the Murdock Underground Coal Mine Site and Surrounding Area.
Source: Base map from Hallbick and Fehrenbacher (1971).

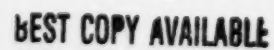


Figure 4.6. Physiography of the Farmland Site and Surrounding Area.
Source: Base map from Willman and Frye (1970).

watershed; the small streams draining this area flow northeastward into the Mazon River, which flows into the Illinois River at Morris. The southwest side of the Marseilles Morainic System drains southwestward through Mud Creek and its tributaries into the Vermillion River, which flows northwestward through Pontiac and Streator, entering the Illinois River at LaSalle.

Small towns located closest to the farmland site are Blackstone, Ransom, Odell, and Cornell; all are about 8 to 13 km (5 to 8 mi) distant. The larger towns of Dwight, Pontiac, and Streator are about 18 to 21 km (11 to 13 mi) from the Alternative D site.

4.2 CLIMATE AND METEOROLOGY

The following discussion of general influences on the climate and meteorology in the state of Illinois applies to the West Chicago site and all of the alternative sites.

The climate of Illinois is typically continental, with cold winters, warm summers, and frequent short-period fluctuations in temperature, humidity, cloudiness, and wind direction. Except for a few low hills in the extreme south and a small unglaciated area in the extreme northwest, the terrain is essentially flat. Differences in elevation have no significant influence on the climate.

Without the protection of natural barriers such as mountain ranges, Illinois experiences the full sweep of the winds, which are constantly bringing air masses from other areas with little local modification. Southeasterly and easterly winds bring mild and wet weather; southerly winds are warm and showery; westerly winds are dry with moderate temperatures; and northwesterly and northerly winds are cool and dry. Winds are controlled by the storm systems and weather fronts that move eastward and northeastward through Illinois.

Storm systems move through the state most frequently during the winter and spring months, causing a maximum of cloudiness during those seasons. Storm systems in summer tend to be weaker and to stay farther north, leaving Illinois with much sunshine interspersed with thunderstorms of comparatively short duration. The retreat of the sun in autumn is associated with variable periods of pleasant dry weather of the Indian summer variety. This season ends rather abruptly with a return to stormy weather, usually beginning in November.

In winter, snow falls frequently and temperatures drop below -18°C (0°F) several times each year. The soil freezes to a depth of about one meter and occasionally remains snow-covered for weeks at a time. During the summer, the

sun heats the entire state quite uniformly. The annual average number of days with temperatures at 32°C (90°F) is near 20. The hot spells usually last only a few days before being relieved by cool air from Canada. The highest temperatures reach 47°C (117°F) in the southern region of the state and the lowest reach -37°C (-35°F) in the northern region.

4.2.1 West Chicago Site (Proposed Action)

4.2.1.1 Temperature

West Chicago has the lowest mean temperature of the sites studied because it is located at the highest latitude. However, being situated about 48 km (30 mi) west of Lake Michigan, its climate is somewhat modified by the lake. The climate of the Kerr-McGee site can be represented by data taken at the nearest station of the National Weather Service, O'Hare Airport, about 24 km (15 mi) northeast of West Chicago.

Monthly average values of daily maximum and minimum temperatures at O'Hare Airport are shown in Table 4.1. The coldest month is January, with a minimum temperature of -9.6°C (14.7°F); the warmest month is July, with a maximum temperature of 28.4°C (83.1°F). The difference between the maximum

Table 4.1. Monthly Averages of Maximum and Minimum Daily Temperature, 1951-1975

Month	Temperature (°F)									
	O'Hare		Ottawa		Peoria		Rushville		Urbana	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Jan	31.1	14.7	32.1	15.5	31.9	15.7	34.5	15.9	33.5	19.0
Feb	34.3	17.8	37.1	20.1	36.0	19.3	40.0	20.7	38.3	22.1
Mar	44.6	26.7	47.1	28.4	46.5	28.1	49.4	28.9	47.7	30.1
Apr	59.4	38.2	63.0	40.6	61.7	40.8	65.3	41.5	62.6	42.0
May	69.7	47.0	73.9	50.6	72.3	50.7	75.7	50.8	73.4	51.8
Jun	79.1	57.0	83.4	60.7	81.7	60.9	84.9	60.8	83.2	61.2
Jul	83.1	60.7	86.1	64.5	85.5	64.6	88.1	64.4	85.5	64.9
Aug	82.3	59.9	84.8	62.7	84.0	62.9	86.6	62.0	83.9	62.7
Sep	75.4	52.0	78.4	55.3	76.4	54.6	80.3	54.5	78.7	55.6
Oct	65.5	42.0	67.3	44.7	65.9	44.0	68.4	44.0	67.1	45.1
Nov	48.3	30.1	50.3	32.3	48.7	31.1	51.9	31.3	49.9	33.1
Dec	35.0	19.2	36.7	21.5	35.7	20.3	38.7	21.5	37.7	23.4

Source: Ruffner (1980); data collected by U.S. National Weather Service.

and minimum temperatures during each month represents the mean diurnal variation for that month. The table indicates that the monthly maximum diurnal temperature variation is 13C° (23.5F°) in October and that the monthly minimum temperature variation is 9C° (15.8F°) in December.

4.2.1.2 Winds

Monthly average values for wind speed and direction at O'Hare Airport are shown in Table 4.2. Monthly mean wind speed ranges from 12.7 to 19.6 km/h (7.9 to 12.2 mph). The maximum wind speed occurs in April, the minimum in July. The prevailing wind direction varies from westerly in January to southerly in October and then swings back quickly to westerly in December. The summer months tend to exhibit lower surface wind speeds, probably due to strong nocturnal inversion conditions. The air near the surface is cooled by surface radiation and is decoupled from the momentum source of the upper atmosphere. The wind rose for West Chicago (based on the O'Hare data) is presented in Figure 4.7.

Wind data are also taken at DuPage County Airport, which is located 6.4 km (4 mi) north-northwest of the West Chicago site. Although data from that airport do not cover a long enough period for climatological analysis,

Table 4.2. Monthly Averages of Wind Speed and Direction, 1951-1975

Month	Wind Speed (mph) and Direction									
	O'Hare		Ottawa		Peoria		Rushville		Urbana	
	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir
Jan	11.4	W	11.4	W	11.2	S	13.1	NW	12.2	NW
Feb	11.4	W	11.6	W	11.6	WNW	13.2	NW	12.4	NW
Mar	11.6	W	11.9	W	12.3	WNW	14.4	NW	13.3	WNW
Apr	12.2	W	11.8	W	12.3	S	14.0	S	13.1	S
May	10.6	SSW	10.4	SSW	10.9	S	12.0	SSW	10.5	SSW
Jun	9.0	SW	9.4	SSW	9.1	S	9.9	SSW	10.0	SSW
Jul	7.9	SW	8.3	SSW	8.0	S	8.4	SSW	9.1	SSW
Aug	8.1	SW	8.1	SSW	7.8	S	8.0	SSW	8.1	S
Sep	8.7	S	9.0	S	8.8	S	9.4	SSW	8.5	S
Oct	9.7	S	9.8	S	9.5	S	10.7	S	8.3	S
Nov	10.9	SSW	11.3	SSW	11.2	S	13.3	S	7.8	S
Dec	10.8	W	11.1	W	10.9	S	13.1	S	7.7	S

Source: Ruffner (1980); data collected by U.S. National Weather Service.

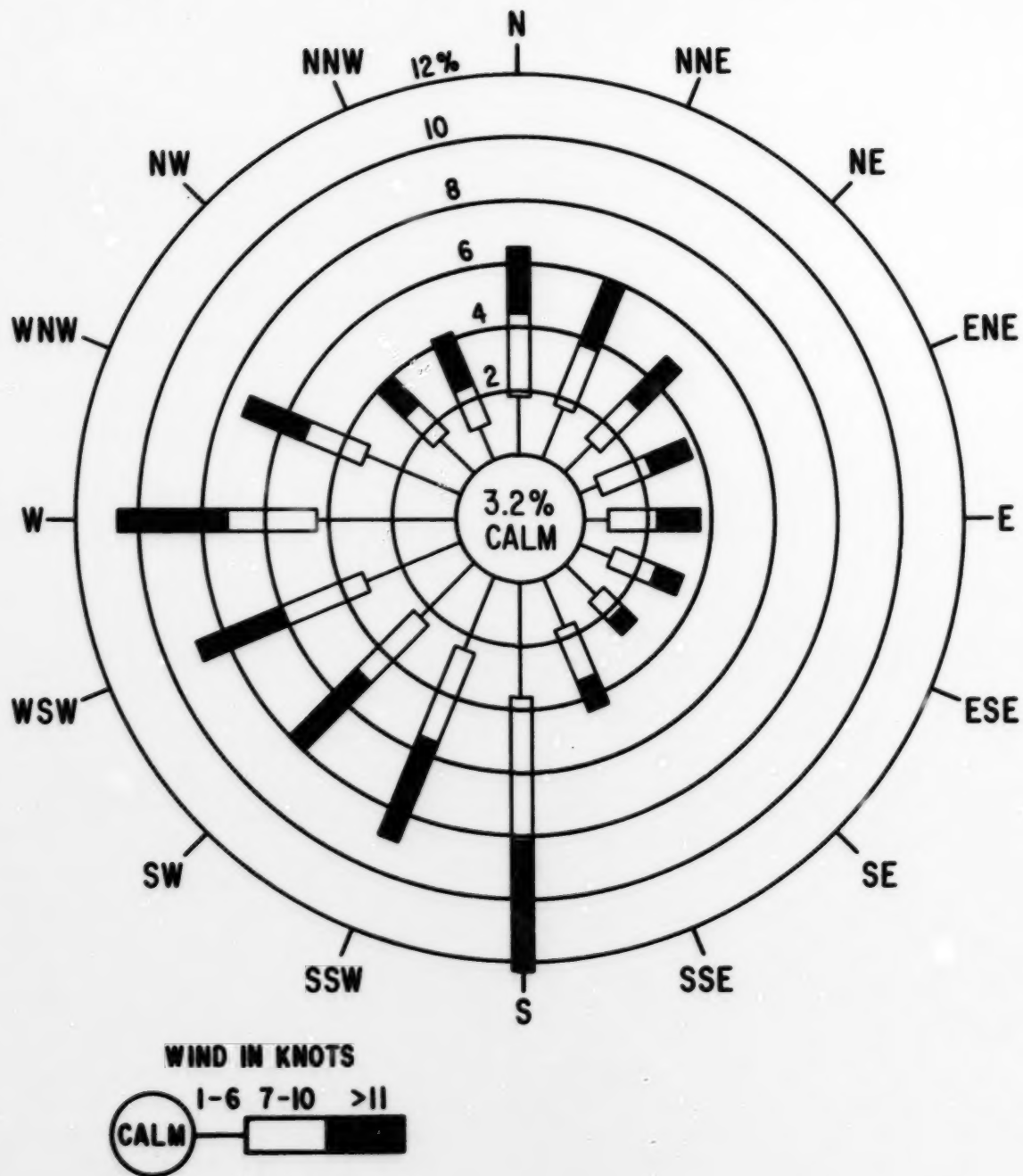


Figure 4.7. Wind Rose for West Chicago, All Stability Classes, January 1970 through December 1974.

Source: FES (Fig. 4.12).

they were adequate to justify the use of O'Hare Airport data for assessment of the site. The correlation coefficient between the wind speeds measured at the DuPage County Airport and those at O'Hare was quite high (0.88).

4.2.1.3 Precipitation

The longer distance from the Gulf of Mexico and the lower air-mass temperatures tend to reduce the amount of precipitation at the West Chicago site compared with the other sites. Mean monthly total and maximum daily total precipitation at the O'Hare station are given in Table 4.3. The mean monthly total precipitation is small in December. It reaches its maximum in June and generally decreases toward the end of the year; the driest month is February. The average annual precipitation in West Chicago is 80.5 cm (31.7 in.). The maximum daily total precipitation is generally larger in summer, probably due to convective thunderstorms. However, an unusually large value of 11.7 cm (4.62 in.) of precipitation has occurred in October.

Table 4.3. Mean Monthly Total and Maximum Daily Total Precipitation, 1951-1975

Month	Precipitation (in.)									
	O'Hare		Ottawa		Peoria		Rushville		Urbana	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Jan	1.70	2.00	1.60	1.62	1.82	4.45	1.57	2.75	1.90	2.43
Feb	1.30	1.47	1.39	0.99	1.50	1.92	1.64	1.85	1.82	1.67
Mar	2.52	1.85	2.51	1.66	2.80	3.39	3.32	3.17	3.07	2.26
Apr	3.38	2.36	3.98	2.46	4.36	5.06	4.33	3.10	4.12	3.09
May	3.41	2.91	3.30	3.02	3.87	3.62	3.94	2.01	3.47	2.48
Jun	4.15	3.09	4.29	2.93	3.91	4.44	4.37	2.85	3.92	3.05
Jul	3.46	2.89	4.44	8.77	3.76	3.56	4.16	3.00	4.42	3.17
Aug	2.73	3.56	3.22	2.97	3.07	4.32	3.91	3.80	3.04	2.92
Sep	3.01	2.92	3.11	2.44	3.55	4.15	3.87	3.25	3.12	3.02
Oct	2.32	4.62	2.45	2.19	2.51	3.70	3.31	4.42	2.55	3.56
Nov	2.10	1.76	1.89	2.13	2.02	2.45	2.07	2.25	2.48	1.97
Dec	1.64	2.13	2.06	2.79	1.89	3.38	2.25	1.85	2.63	2.74

Source: Ruffner (1980); data collected by U.S. National Weather Service.

4.2.1.4 Storms

Heavy snows (greater than 15.2 cm [6 in.]) occur on the average only once or twice per year. In January 1979, storms brought more than 101.6 cm (40 in.) of snow to Chicago and its suburbs. Severe ice storms occur only once every four or five years. Icing damaged many transmission lines in Chicago and its suburbs early in the spring of 1985.

Thunderstorms are common in the summer and may be accompanied by hail or destructive windstorms. The high rates of summer rainfall cause runoff and soil erosion. Tornadoes are quite common from March to June. Floods occur at least once or twice nearly every year. The area frequently has late winter or early spring flooding related to the breakup of river ice, especially if there is appreciable melting of snow cover by rain or unseasonably warm weather.

4.2.2 Active Surface Coal Mine (Alternative A)

The Alternative A site is the Rapatee Mine near Farmington, about 48 km (30 mi) west of Peoria. The general factors influencing its climate are described in the introduction to Section 4.2. The meteorological data used in the current analysis were taken at the nearest National Weather Service station in Peoria. These data should be fairly representative because the terrain surrounding the site is quite flat.

4.2.2.1 Temperature

Monthly average values of daily maximum and minimum temperatures at Peoria are given in Table 4.1. These values are 0.56 to 2.2C° (1 to 4F°) higher than corresponding values at the O'Hare station, mainly due to the difference in latitude. The maximum and minimum temperatures at Peoria occur in July and January, respectively, as was true at O'Hare Airport. Monthly mean diurnal temperature variations reach a maximum of 12.1C° (21.9F°) in October and a minimum of 8.6C° (15.4F°) in December.

4.2.2.2 Winds

The mean wind speeds shown in Table 4.2 for Peoria vary from 12.6 to 19.8 km/h (7.8 to 12.3 mph). These values, as well as the seasonal patterns of wind speeds, are almost identical to those at the O'Hare station. However, the wind directions are significantly different; the wind direction at Peoria is southerly almost all the time, except in February and March, and it never becomes westerly as at O'Hare. The Peoria station is affected more by the warm and moist air masses from the Gulf of Mexico than by the cold and dry air flows from Canada.

4.2.2.3 Precipitation

The mean monthly total precipitation in Peoria is relatively small at the beginning of the year and rapidly rises to a maximum of 11.1 cm (4.36 in.) in April (Table 4.3). It decreases slightly but remains abundant and fairly constant from May to September and finally decreases quickly toward the end of the year. The average annual precipitation at the Rapatee Mine site is 89.1 cm (35.1 in.). The maximum daily total precipitation does not seem to have any seasonal pattern; it occurs almost randomly, indicating that large precipitation events may occur any time of the year, although their frequencies should depend upon the season. The maximum daily precipitation totals in Peoria generally are considerably larger than those at the O'Hare station (Table 4.3). Thus, in terms of precipitation, the Rapatee Mine is a less desirable location than the West Chicago site.

4.2.2.4 Storms

Because of the latitude difference, there are fewer snowstorms but more rainstorms in Peoria than at O'Hare Airport. Thunderstorms are common in late spring and early summer, and occasionally are accompanied by windstorms and tornadoes. The maximum precipitation in 24 hours was 14 cm (5.5 in.), which occurred in May 1927; the maximum snowfall in 24 hours was 45.7 cm (18.0 in.), which was recorded in February 1900.

4.2.3 Reclaimed Surface Coal Mine (Alternative B)

The Alternative B site is located in western Peoria County, which has only slight topographic relief. The general influences on local meteorology are described in the introduction to Section 4.2. Meteorological data taken at the Rushville station, which is about 68 km (42 mi) southwest of the site, will be used in the current assessment.

4.2.3.1 Temperature

The monthly average values of daily maximum and minimum temperatures for Rushville are shown in Table 4.1. The coldest month is January and the warmest is July. The monthly average temperatures vary from 1.39 to 31.2°C (34.5 to 88.1°F) for the daily maximum and from -8.94 to 18°C (15.9 to 64.4°F) for the daily minimum. The monthly diurnal temperature variation reaches a peak of about 14.3°C (25.8°F) in September and a minimum of about 9.5°C (17.2°F) in December.

4.2.3.2 Winds

The mean speeds at Rushville (Table 4.2) range from 12.9 to 23.2 km/h (8 to 14.4 mph). The values are generally larger than those at the other stations considered. High wind speeds help to disperse pollution because pollutant concentrations are inversely proportional to wind speed. However, high wind may also increase particle resuspension from the surface, particularly during field operations when surface vegetation is stripped and the soil is loose and dry. Wind speeds are generally slower in summer and faster in spring (Table 4.2). Wind directions vary widely from northwesterly in January to southerly in December. The wind rose for the Peoria area, based on meteorological data taken at the Rushville Station, is shown in Figure 4.8.

4.2.3.3 Precipitation

The mean monthly total precipitation for Rushville (Table 4.3) ranges from a low of 3.99 cm (1.57 in.) in January to a high of 11.1 cm (4.37 in.) in June. The average annual precipitation is 98.3 cm (38.7 in.). Maximum daily total precipitation varies from 4.7 to 11.2 cm (1.85 to 4.42 in.). The values for both total and daily precipitation are generally slightly larger than those at the O'Hare Airport station. The excessive rainfall in Rushville is one disadvantage of the Alternative B site.

4.2.3.4 Storms

Thunderstorms are quite common in spring and summer due to passage of weather fronts and local convection. Windstorms and tornadoes also occur occasionally, particularly in late spring during weather front passages.

4.2.4 Underground Coal Mine (Alternative C)

The Alternative C site is the Murdock Mine and the No. 5 Mine near Murdock in Douglas County, Illinois, about 48 km (30 mi) south of Urbana. This site is expected to have the warmest climate and the least amount of snow among the sites being considered. The meteorological data used in this analysis were collected at Chanute Air Force Base in Rantoul, which is about 23 km (14 mi) north of the city of Urbana.

4.2.4.1 Temperature

The monthly average temperatures shown in Table 4.1 for Urbana range from 0.83 to 29.7°C (33.5 to 85.5°F) for daily maximum values and from -7.2 to 18.3°C (19.0 to 64.9°F) for daily minimum values. The coldest month occurs in January and the warmest month in July. The temperatures in winter months are generally higher for the Urbana station than for any of the other stations

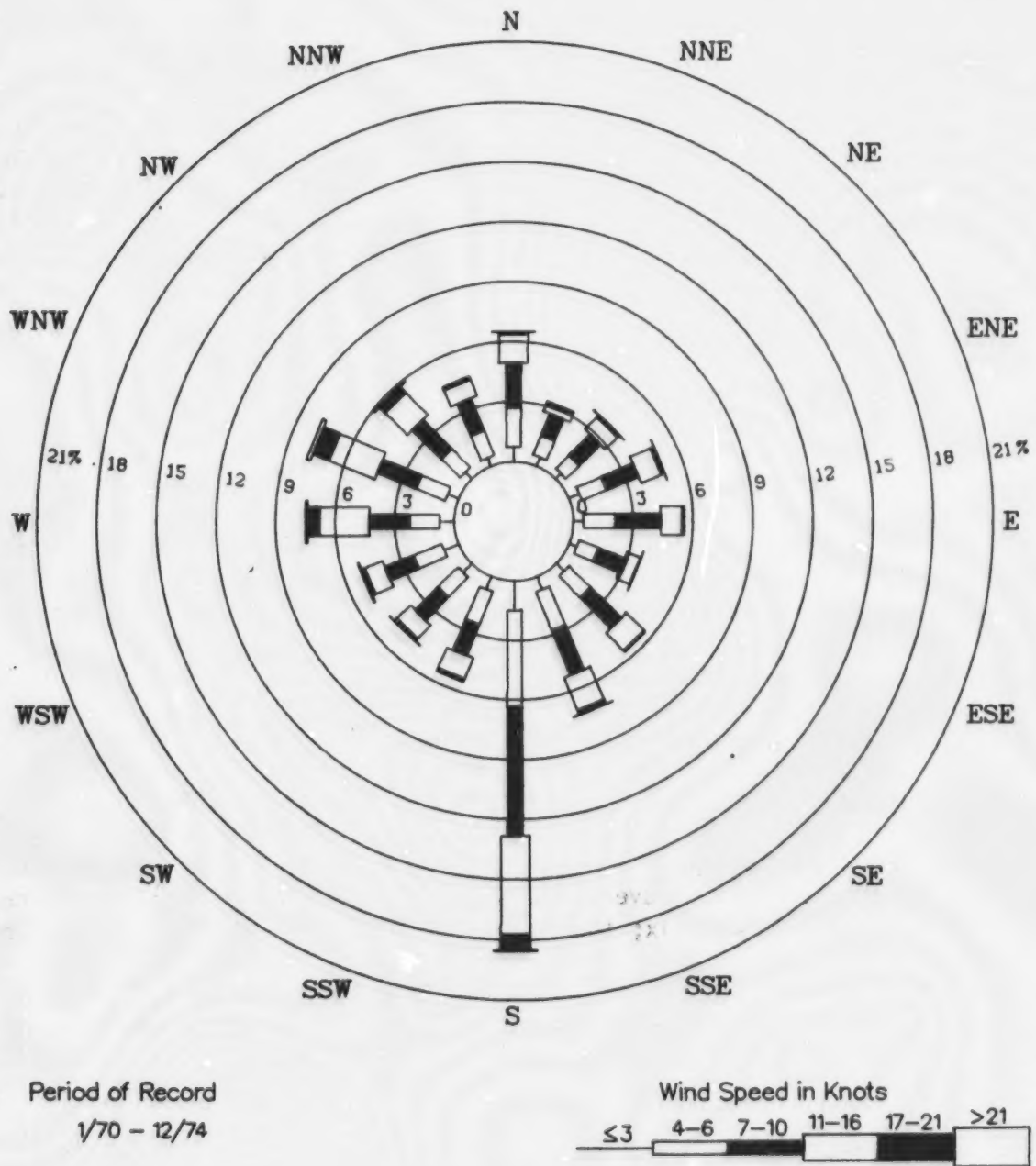


Figure 4.8. Annual Wind Rose for Peoria.

considered. The largest mean diurnal variation is 12.8°C (23.1°F), which occurred in September; the smallest is 7.9°C (14.3°F), which occurred in December.

4.2.4.2 Winds

The mean wind speeds for Urbana (Table 4.2) range from 12 to 21 km/h (7.7 to 13.3 mph). The values decrease in a fairly orderly fashion from the beginning to the end of the year. The maximum wind speed occurs in late winter and early spring, with the minimum in December. The wind direction varies from northwesterly in January to southerly in December, indicating that the climate in the winter months is affected more by cold, dry air from Canada and in the summer months more by warm, moist air from the Gulf of Mexico. The wind rose for Urbana (Rantoul/Chanute) is given in Figure 4.9.

4.2.4.3 Precipitation

The monthly mean precipitation for Urbana ranges from 4.62 cm (1.82 in.) in February to 11.2 cm (4.42 in.) in July (Table 4.3). The low value in February is probably affected by cold dry air from Canada, as indicated by the wind direction (Table 4.2). The high value in summer apparently results from local convection and from moist air from the Gulf of Mexico. The maximum daily total precipitation ranges from 4.2 cm (1.67 in.) in February to 9.0 cm (3.56 in.) in October; the average annual precipitation is 92.7 cm (36.5 in.). In comparison with the O'Hare station, the precipitation in Urbana is slightly higher, which is a disadvantage of the Alternative C site.

4.2.4.4 Storms

Thunderstorms are quite common, and wind storms and tornadoes occur occasionally. The annual average number of days with rainfall more than 2.54 cm (1 in.) is about six; the number of days with snowfall over 25.4 cm (10 in.) is about two.

4.2.5 Farmland Site (Alternative D)

The Alternative D site is located in north-central Livingston County, about 72 km (45 mi) southwest of Joliet. The meteorological data used in this analysis are from Ottawa, which is about 32 km (20 mi) northwest of the site.

4.2.5.1 Temperature

Monthly average temperatures for Ottawa are given in Table 4.1. The coldest month is January and the warmest is July. Temperatures range from 0.2 to 30.1°C (32.3 to 86.1°F) for the daily maximum and from -9.2 to 18.1°C (15.5

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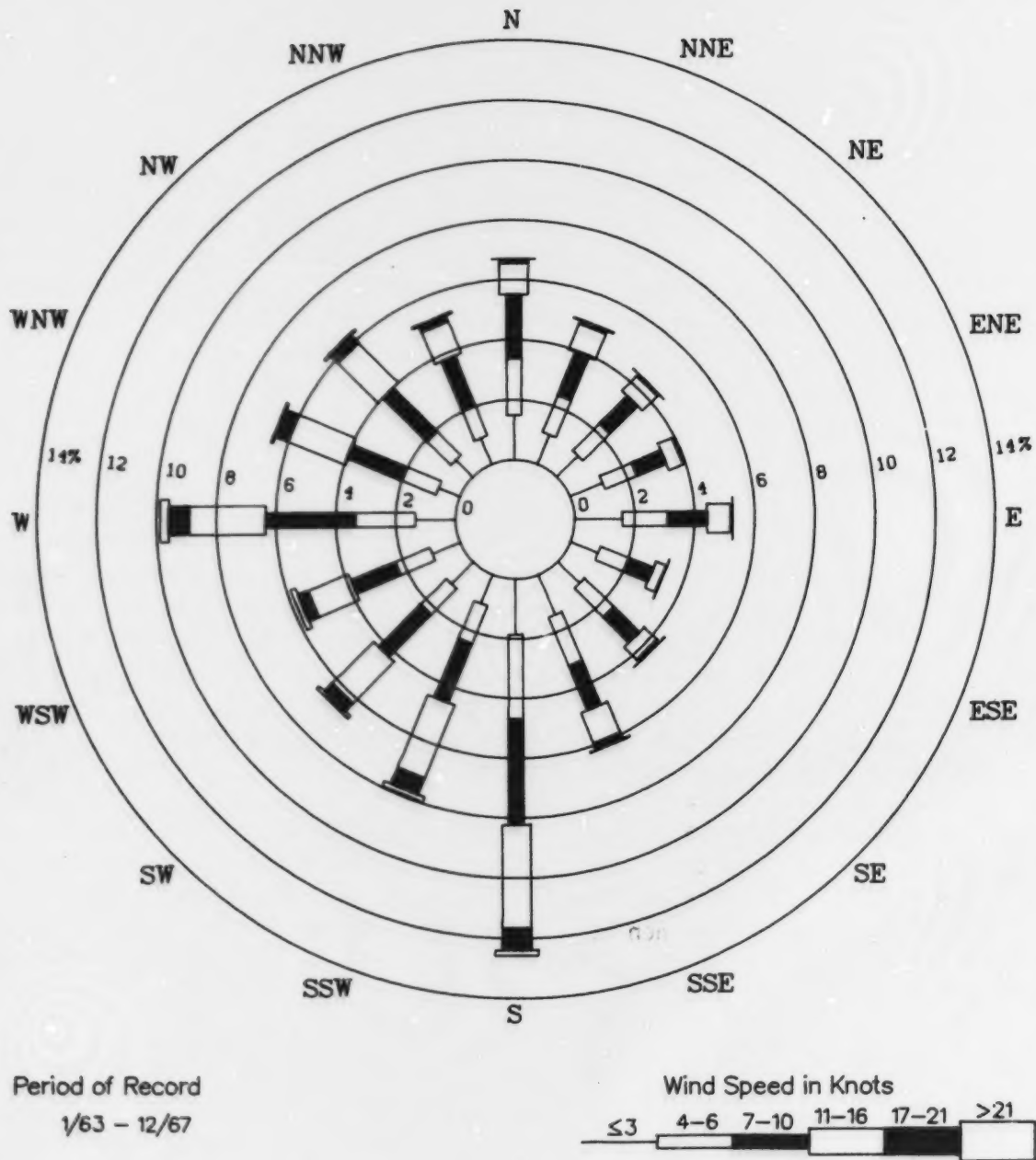


Figure 4.9. Annual Wind Rose for Rantoul/Chanute.

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to 64.5°F) for the daily minimum. Diurnal variation peaks (incremental change) at about 12.8C° (23F°) in March and September and reaches its lowest value of 8.4C° (15.1F°) in December.

4.2.5.2 Winds

The monthly average wind speeds and wind directions at Ottawa are shown in Table 4.2. The wind speed ranges from 13 to 19 km/h (8.1 to 11.9 mph) and is generally smaller during the summer. The prevailing wind direction varies from westerly in winter and spring, to south-southwesterly in summer, and to southerly in autumn. The wind rose for Ottawa is similar to the one shown in Figure 4.7 for West Chicago.

4.2.5.3 Precipitation

The monthly mean precipitation in Ottawa ranges from a minimum of 3.53 cm (1.39 in.) in February to a maximum of 11.3 cm (4.44 in.) in July (Table 4.3). The average annual precipitation is 86.9 cm (34.2 in.). The maximum daily total precipitation varies from a low of 2.51 cm (0.99 in.) in February to a high of 22.3 cm (8.77 in.) in July. The July value is considerably higher than the maximum values for the other stations considered. Except for this unusual case, the amounts and seasonal patterns of precipitation at the Ottawa and O'Hare stations are approximately the same.

4.2.5.4 Storms

As is true for the O'Hare station, heavy snows (greater than 15 cm [6 in.]) occur about once or twice a year. Thunderstorms are common in the summer and may be accompanied by hail or windstorms. Tornadoes commonly occur in late spring and earlier summer. Floods occur once or twice a year, most likely during late winter when rain combines with melting snow.

4.2.6 Air Quality Standards and Ambient Air Quality

The important nonradioactive pollutants resulting from waste-disposal operations would be combustion products of diesel fuel and particulates, which would be emitted in large quantities during transport of the wastes. The ambient concentrations of these pollutants and the applicable federal and state air quality standards are summarized in Table 4.4. Primary standards are to protect public health, whereas secondary standards are to ensure public welfare and environmental protection (state and federal air quality standards are identical). No data were available in many instances for the specific waste-disposal sites, so data available for locations nearest the sites are given to provide some indication of ambient air quality at the sites. The nearby locations accurately reflect the conditions at the sites but do not

Table 4.4. Air Quality Data at or near the Alternative Disposal Sites, 1984

Site	TSP ^a ($\mu\text{g}/\text{m}^3$)		Sulfur Dioxide ($\mu\text{g}/\text{m}^3$)			Nitrogen Dioxide ($\mu\text{g}/\text{m}^3$)	Carbon Monoxide (mg/m^3)		Lead ($\mu\text{g}/\text{m}^3$)
	Annual	24-hour	Annual	24-hour	3-hour	Annual	8-hour	1-hour	Quarterly
West Chicago	44	111	-	-	-	-	-	-	-
Elgin	42	92	14.3	71	156	-	-	-	0.21
Lemont	-	-	-	-	-	28.6	-	-	-
Peoria	37	113	22.9	151	212	-	12.2 ^b	17.5	0.27
Springfield	34	103	17.1	160	276	-	9.0	14.0	-
Joliet	44	126	22.9	103	223	-	5.8	12.6	0.16

State and federal primary standards	75	260	80.0	365	None	100.0	10.0	40.0	1.50
State and federal secondary standards	None	150	None	None	1,300	100.0	10.0	40.0	1.50

^a TSP = Total suspended particulates.

^b According to more recent data for 1985 and 1986 (through October), concentrations are less than the state and federal standards. The maximum ambient value is $7.7 \text{ mg}/\text{m}^3$, indicating attainment conditions; this value is used in subsequent discussions in the text.

Source: Illinois Environmental Protection Agency (1985).

give best estimates. The Elgin and Lemont data were included to provide estimates of the SO_2 , NO_2 , and CO data that are missing for the West Chicago site. It was assumed that the Peoria data are representative of ambient air quality at the active and reclaimed coal mine sites in Fulton and Peoria counties, the Springfield data are representative of the underground coal mine in Douglas County, and the Joliet data are representative of the farmland site in north-central Livingston County.

The values for all pollutants at all sites are below the primary and secondary standards. The largest annual average value for total suspended particulates (TSP) is $44 \mu\text{g}/\text{m}^3$, which occurs at Joliet and West Chicago. The largest 24-hour average TSP value is $126 \mu\text{g}/\text{m}^3$ at Joliet, a value that is below both the primary and secondary standards. The sulfur dioxide, nitrogen dioxide, and lead concentrations are considerably below both the primary and secondary standards.

4.3 DEMOGRAPHY AND SOCIAL PROFILE

4.3.1 West Chicago Site (Proposed Action)

4.3.1.1 Demography

West Chicago lies mainly in Winfield Township and partly in Wayne Township at the western edge of DuPage County. The DuPage County population was 658,835 as of the 1980 census (U.S. Bur. Census 1983), an increase of 33.6% over the prior decade of the 1970s (Table 4.5). The DuPage County population is projected to increase by 36% to 895,884 people by the year 2000 (Ill. Bur. Budget 1984). As of 1980, over 98% of the DuPage County population lived in urban areas (Table 4.5). The West Chicago site is situated in the middle of a densely populated residential area.

4.3.1.2 Transportation

The Regional Transportation Authority operates one bus route (No. 635) in West Chicago. Route 635 runs from the Chicago and Northwestern Railroad station in West Chicago to the southeastern section of the city. The bus route passes within a few blocks of the Kerr-McGee facility. Three railroad companies also service West Chicago: the Chicago and Northwestern, the Burlington Northern, and the Elgin, Joliet and Eastern (EJ&E). The Chicago and Northwestern passes through the center of West Chicago and provides both freight and commuter service on its main line out of the Midwest to the West. One of the freight lines is on the north side of town and services the growing industrial parks there. The Burlington Northern and EJ&E also operate freight lines. The EJ&E is a north-south freight line and the railroad -- and/or its access roadway -- forms the western boundary of the Kerr-McGee facility.

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Table 4.5. Demographic Profile of the Illinois Counties in Which the Alternative Sites are Located

County	Population, 1970	Population, 1980	Percent Change in Population, 1970-1980	Percent Urban Population, 1980
Douglas	18,980	19,774	+4.1	46.8
DuPage	493,292	658,835	+33.6	98.4
Fulton	41,883	43,687	+4.3	46.9
Livingston	40,705	41,381	+1.7	45.8
Peoria	195,730	200,466	+2.6	84.3

County	Projected Population, 2000	Projected Percent Change in Population, 1980-2000	Population Density, 1980 (no./mi ²)	
Douglas	21,491	+8.7	47.4	
DuPage	895,884	+36.0	1,957.0	
Fulton	48,895	+11.9	50.2	
Livingston	42,432	+2.5	39.6	
Peoria	204,683	+2.1	323.0	

Source: Projected population figures are calculated from data published by the Illinois Bureau of the Budget (1984); all other data from U.S. Bureau of the Census (1983).

4.3.1.3 Property Values

A survey conducted of DuPage County residents in 1976 (Bammi 1976) determined that about 80% of the county's residents lived in single-family homes, 13% in apartments, 6% in townhouses, and the remainder in duplexes and condominiums. No families were reported living in mobile homes. In 1981, the average sale price of single-family homes within a 1.6-km (1-mi) radius of the West Chicago site was \$63,400, ranging from \$45,000 to \$71,000 (Barclay and Mabus 1982). As of November 1982, the average list price of single-family residences on the market in West Chicago was \$62,400, ranging from \$30,900 to \$175,000 (Barclay and Mabus 1982). The housing market in the West Chicago area has kept pace with increases in housing prices throughout the Chicago area.

The city of West Chicago, as a subgrantee of DuPage County, has received approval from the U.S. Department of Housing and Urban Development (HUD) for funds to provide low-cost loans and grants to upgrade an area just across the EJ&E Railroad tracks from the Kerr-McGee facility (about four blocks north-northwest). The DuPage County Development Commission presented data to HUD indicating that loans and grants were necessary to rehabilitate this area (see Figure 4.10) and to eliminate slums, blight, and blighting influences.

Current evidence does not conclusively indicate that the entire housing market for the area surrounding the Kerr-McGee facility has been influenced by its proximity to the facility. However, evidence indicates that older (pre-1950) homes within a two-block radius of the perimeter of the site did experience significant declines in value relative to newer (post-1950) homes within 1.6 km (1 mi) of the site and older homes more than two blocks from the site (Payne et al. 1987). Statistics indicating whether this trend of declining property values has continued past 1982 for older homes near the facility have not yet been made available. Various realtors (Bennett 1978;



Figure 4.10. Map of Part of the Residential Rehabilitation Area as Applied for by the City of West Chicago. The portion of the Kerr-McGee facility indicated on the map is not part of the rehabilitation area.

Source: FES (Fig. 4.17, as modified from West Chicago City Newsletter, Inaugural Edition, Vol. 1, No. 1, May-June 1978).

Schmeling 1978; Strayve 1978) believe that the Kerr-McGee facility causes reductions in property values ranging from 3 to 15% up to six or eight blocks away; these opinions are not based on any systematic analysis.

Data compiled by Barclay and Mabus (1982) indicate that the average sale price of residences within an 0.8-km (0.5-mi) radius of the facility has increased from 1977-1978 to 1981 at a rate 20% slower than that of comparable residences in the nearby towns of Winfield and Warrenville (5.6 and 9.6 km [3.5 and 6 mi] distant, respectively). Moreover, the average number of days on the market has increased at a comparatively faster rate for the residences near the facility. Data on the average assessed value of randomly selected residences within a three-block radius of the Kerr-McGee facility from 1971 to 1979, when compared with the average assessed value of randomly selected residences in Winfield and Warrenville over the same time period, indicate that the assessed value of the residences near the Kerr-McGee facility increased at a 3.5% slower rate (see Table 4.6). A similar trend was apparent when residences of about the same age in both areas were compared.

Recent research has demonstrated that for a short time after a severe accident, there is a link between residential property values and proximity to nuclear power plants. However, it is not possible to generalize these results beyond the study areas considered in those reports (Gamble and Downing 1981; Gamble et al. 1979).

4.3.1.4 Taxes

Kerr-McGee holdings in West Chicago pay into the following taxing entities: DuPage County, County Highway, T.B. Sanitarium, County Health Department, County Bridge Tax, County Highway Matching Tax, County Home Addition, and Junior College 502. According to the data in Table 4.7, the assessed value of the Kerr-McGee property declined to a low of \$79,620 from 1975 to 1980, increased slightly in 1981, and declined again in 1983. The tax contribution of the Kerr-McGee property to DuPage County in 1985 was \$5,257.

4.3.2 Active Surface Coal Mine (Alternative A)

4.3.2.1 Demography

Alternative A, the Rapatee Mine, is located in the northern portion of Fulton County near the border of Knox County. The Fulton County population was 43,687 as of the 1980 census (U.S. Bur. Census 1983). The county had experienced 4.3% growth through the 1970s, or just above the average growth rate for the entire state (Table 4.5). It is projected to experience an 11.9% increase in population by the year 2000, which would increase population

Table 4.6. Percent Increase in Assessed Value of Randomly Selected Residences in West Chicago as Compared with Randomly Selected Residences in Winfield and Warrenville^a

Type of Property	1971-1975		1975-1979		1971-1979	
	West Chicago (N=19)	Winfield and Warrenville (N=18)	West Chicago (N=19)	Winfield and Warrenville (N=19)	West Chicago (N=19)	Winfield and Warrenville (N=18)
All property	16.2	22.5	6.5	3.9	23.8	27.3
Old property (pre-1950)	24.9	33.4	9.1	4.8	36.3	39.8
New property (post-1950)	8.9	16.7	4.0	3.3	13.3	20.6

^a West Chicago residences are located within a three-block radius of the Kerr-McGee facility. Data were collected by S.J. Olshansky of Argonne National Laboratory at the Winfield Township Assessor's Office on November 5, 1982.

Source: FES (Table 4.11A).

density to 21.7/km² (56.1/mi²) compared with 19.4/km² (50.2/mi²) in 1980 (Ill. Bur. Budget 1984). Just under 47% of the county population lived in urban areas as of the 1980 census.

The Rapatee Mine is located approximately 14.5 km (9 mi) from the eastern border of the county and is just south of the Knox County border. Nearby towns in Fulton County, their 1982 populations, and their locations relative to the site include: Farmington (3,118; 12.9 km east); London Mills (587; 8 km west); and Fairview (594; 8 km south) (U.S. Dept. Transp. 1982-1984). The largest city near the site is Canton (14,626; 24.2 km south-southeast). In Knox County, the nearest town is Maquon (350; 9.7 km north) (U.S. Dept. Transp. 1982-1984).

4.3.2.2 Transportation

The transportation route to the disposal site is shown in Figure 5.2.

4.3.2.3 Property Values

At the active surface coal mine site, one acre of unreclaimed land is currently selling for about \$400 whereas one acre of reclaimed land is currently selling for about \$900 (see Table 4.8). Based on estimates provided

Table 4.7. Tax Contributions to DuPage County by
Kerr-McGee, 1971-1985^a

Year	Assessed Value of Kerr-McGee Property (\$)	Taxes Paid by Kerr-McGee (\$)	Total Taxes Collected by DuPage County (million \$)	Percentage of DuPage County Taxes Paid by Kerr-McGee
	(1)	(2)	(3)	(4)
1971	633,990	45,140	153.6	0.029
1972	634,190	46,131	167.5	0.028
1973	634,190	47,349	183.2	0.026
1974	634,190	45,821	199.1	0.023
1975	79,620	5,755	213.3	0.003
1976	79,620	6,258	240.6	0.003
1977	79,620	6,876	278.8	0.002
1978	79,620	7,713	311.0	0.002
1979	79,620	8,005	330.1	0.002
1980	79,620	8,506	374.0	0.002
1981	84,620	9,776	420.0 ^b	0.002
1982	84,620	10,000 ^b	-	-
1983	60,480	5,000	-	-
1984	60,480	5,061	-	-
1985	60,480	5,257	-	-

^a Data for columns 1 and 2 were collected by S.J. Olshansky of Argonne National Laboratory at the Winfield Township Assessor's Office. The 1971-1981 data were collected on November 5, 1982; the 1982-1985 data were collected on June 25, 1986. The data for column 3 were provided by J. Miller of the DuPage County Treasurer's Office.

^b Estimated.

Source: FES (Table 5.A) and new data for 1982-1985.

Table 4.8. Estimated Property Values at Alternative Sites
for the Kerr-McGee Wastes

Site	County	\$ per Acre, 1986
Active surface coal mine	Fulton	900 (reclaimed land) 400 (unreclaimed land)
Reclaimed surface coal mine	Peoria	800
Underground coal mine	Douglas	1,800-2,400
Farmland site	Livingston	1,200-1,500

Sources: Knox, Schroff (1986); Peoria, Maloof (1986); Douglas, Snyder (1986); and Livingston, Hamilton (1986).

by Maloof (1986), farmland in the vicinity of the site is now selling for about \$1,500-2,500 per acre.

4.3.2.4 Taxes

Data are not available on the exact tax contributions to Fulton County from the land owned by Peabody Coal Company. However, because the acreage under consideration is small, its tax contribution to the county would be expected to be nominal.

4.3.3 Reclaimed Surface Coal Mine (Alternative B)

4.3.3.1 Demography

Alternative B, the Elm Mine, is located in the southwest portion of Peoria County in Elmwood Township. Cities located near the site include Farmington (3,118; 6.4 km west), Elmwood (2,117; 8 km northwest), and Hanna City (1,361; 14.4 km east) (U.S. Dept. Transp. 1982-1984). The largest population center near the site is the city of Peoria located 24 km (15 mi) to the east of the site.

The Peoria County population in 1980 was 200,466, which represents a 2.6% increase during the 1970s (U.S. Bur. Census 1983) (see Table 4.5). Projections indicate that Peoria County's population is likely to increase by 2.1% by the year 2000 (Ill. Bur. Budget 1984). Such a population increase would increase population density to 127 km² (330/mi²) from 125 km² (323/mi²) in 1980. As of 1980, 84.3% of Peoria County's population lived in urban areas, primarily in Peoria and its suburbs.

4.3.3.2 Transportation

The transportation route to the disposal site is shown in Figure 5.2.

4.3.3.3 Property Values

One acre of land in the vicinity of the Alternative B site is currently selling for about \$800 (see Table 4.8). It is reasonable to expect that farmland near the Elm Mine is now selling for two to three times the value of one acre of land at the mine site.

4.3.3.4 Taxes

Data are not available on the exact tax contributions to Peoria County from the land owned by local farmers. However, because the acreage under consideration is small, its tax contribution to the county would be expected to be nominal.

4.3.4 Underground Coal Mine (Alternative C)

4.3.4.1 Demography

Alternative C, the Murdock and No. 5 mines, is located in the east-central portion of Douglas County. The Douglas County population was 19,774 in 1980 (U.S. Bur. Census 1983), the smallest county population of all those considered (see Table 4.5). The Douglas County growth rate from 1970 to 1980 was 4.1%, or 1.3% higher than the average population increase for the state. Projections indicate that the Douglas County population will increase by 8.7% by the year 2000, which would increase population density to $19.9/\text{km}^2$ ($51.5/\text{mi}^2$) by comparison with $18.3/\text{km}^2$ ($47.4/\text{mi}^2$) in 1980 (Ill. Bur. Budget 1984). Only 46.8% of the Douglas County population lived in urban areas as of the 1980 census.

Cities located near the Alternative C mines include Newman (1,079; 6.4 km east), Camargo (428; 6.4 km west), and Villa Grove (2,707; 14.4 km northwest) (U.S. Dept. Transp. 1982-1984).

4.3.4.2 Transportation

The transportation route to the disposal site is shown in Figure 5.2.

4.3.4.3 Property Values

Farmland in the immediate vicinity of the Alternative C site is currently selling for about \$1,800 to \$2,400 per acre (see Table 4.8). The land at the

site is thought to be worth slightly more than the farmland surrounding it (Snyder 1986).

4.3.4.4 Taxes

Data are not available on the exact tax contributions to Douglas County from the land owned by Ziegler Coal Company. However, because the acreage under consideration is small, the amount of its tax contribution to the county would be expected to be nominal.

4.3.5 Farmland Site (Alternative D)

4.3.5.1 Demography

The farmland under consideration for the farmland disposal site (Alternative D) is located in the north-central portion of Livingston County within a 23.3-km² (9-mi²) quadrant in the southeastern portion of Sunbury Township. As of the 1980 census (see Table 4.5), the Livingston County population was 41,381, or 1.7% larger than in 1970 (U.S. Bur. Census 1983). Projections indicate that it will grow by 2.5% by the year 2000 (Ill. Bur. Budget 1984). Population density was 15.3/km² (39.6/mi²) in 1980 and is projected to increase to 15.7/km² (40.6/mi²) by the year 2000. As of the 1980 census, 45.8% of the county population lived in urban areas.

Cities located near the farmland under consideration include Odell (1,083; 8 km southeast), Dwight (4,146; 14.4 km northeast), Cornell (603; 9.6 km southwest), and Pontiac (11,227; 14.4 km south) (U.S. Dept. Transp. 1982-1984).

4.3.5.2 Transportation

The transportation route to the disposal site is shown in Figure 5.2.

4.3.5.3 Property Values

The farmland under consideration in Livingston County is currently selling for approximately \$1,200 to \$1,500 per acre, depending upon the current use of the land (see Table 4.8).

4.3.5.4 Taxes

Data are not available on the exact tax contributions to Livingston County from the land that is privately owned near the Alternative D site. However, because the acreage under consideration is small, the amount of its tax contribution to the county would be expected to be nominal.

4.4 LAND OWNERSHIP AND USE

4.4.1 West Chicago Site (Proposed Action)

The West Chicago site, which contains the remains of the Kerr-McGee facility and disposal area, is surrounded by a fence and marked with radioactivity warning signs. It is bordered on the north by Ann Street; on the east by Factory Street; on the west by the EJ&E Railroad tracks; and on the south by an industrial park, a restaurant, and a bowling alley. Open areas of land occur west of the railroad tracks. Located east of the site are Williams Advance Sheet Metal Company, a planned unit development area, residential homes, vacant lots, and the West Chicago Terrace home for the elderly. In the general vicinity of the site, the city of West Chicago is primarily residential to the east and northeast, commercial directly to the north (in the center of the town), and limited to general manufacturing to the west and north end of the city.

Most of the major West Chicago schools and Pioneer Park lie within 490 m (1,600 ft) of some part of the Kerr-McGee property. These schools are West Chicago High School, Pioneer Elementary School, Gary Elementary School, West Chicago Junior High School, and Lincoln Elementary School (Salmon 1978). Their combined enrollment is approximately 80% of the West Chicago public school population.

The West Chicago site is located in DuPage County, which -- in comparison with the other counties under consideration -- has the lowest percentage of land in farms, at 21.2%. Such a low percentage is expected because DuPage County is a growing, heavily urbanized area. The growth of urban areas is evidenced by the fact that the acreage for farms, cropland, and woodland declined rapidly within the four-year period from 1978 to 1982 (see Table 4.9). This trend toward urbanization of DuPage County is expected to continue.

4.4.2 Active Surface Coal Mine (Alternative A)

The 8-ha (20-acre) Alternative A site is located in Fulton County, where 77.1% of the land is currently used for farming (U.S. Bur. Census 1983; see Table 4.9). In 1982, the total farm acreage for the county was 422,041, a 2.4% decline from 1978. Total cropland acreage also declined from 1978 to 1982, whereas harvested cropland acreage and total woodland acreage increased by 1.6 and 5.3%, respectively, since 1978 (see Table 4.9). In comparison with the other counties, Fulton County is one of only two counties to experience an increase in cropland acreage. Its decline in farm acreage was the smallest of the counties under consideration.

Table 4.9. Land-Use Characteristics of Illinois Counties under Consideration as Sites for the Kerr-McGee Wastes, 1982

County	Total Cropland		Harvested Cropland		Total Woodland	
	acres	% ^a	acres	% ^a	acres	% ^a
DuPage	29,480	-27.6	28,286	-23.7	1,056	-9.8
Douglas	260,908	+2.0	252,560	+2.7	4,848	+12.4
Fulton	299,473	-2.7	264,319	+1.6	72,038	+5.3
Livingston	594,562	-2.3	575,664	-1.1	6,430	-7.9
Peoria	231,630	-2.5	216,662	-0.7	24,795	-5.3

County	Land in Farms		Percent Land in Farms ^b			
	acres	% ^a				
DuPage	32,560	-27.5	21.2			
Douglas	276,455	+2.5	100.0			
Fulton	422,041	-2.4	77.1			
Livingston	627,653	-2.6	96.5			
Peoria	281,122	-3.6	73.1			

^a Percent change for the time period 1978 to 1982.

^b Percent land in farms is an approximate figure because of the process of estimation for land that is crossed by county boundary.

Source: U.S. Bureau of the Census (1983).

No cropland or woodland exists in the immediate vicinity of the site because the site is an active strip mine. The mine is owned by the Midland Coal Company, and the land from which the coal is extracted is owned by the Peabody Coal Company.

4.4.3 Reclaimed Surface Coal Mine (Alternative B)

The 8-ha (20-acre) Alternative B site is located in the western portion of Peoria County in Elmwood Township. As of 1980, Peoria County had just over 73% of all of its land in use as farms (U.S. Bur. Census 1983; see Table 4.9). From 1978 to 1982, there were declines in farm acreage, cropland acreage, harvested cropland, and total woodland acreage. Currently, approximately 114,000 ha (281,000 acres) of land is in use as farms. Because a high percentage of Peoria County's population currently resides in the Peoria metropolitan area in the far eastern portion of the county, the land under

consideration in the western portion of the county is comparable to that of the other alternatives.

Most of the land in the vicinity of the site is currently used as pastureland by local farmers, and the land is owned privately. Some portions of the land are pitted and filled with water. Some of the pits are large enough to be considered lakes, and these larger water bodies are used for recreational activities.

4.4.4 Underground Coal Mine (Alternative C)

The 77-ha (190-acre) Alternative C site is located in the northern portion of Douglas County, which is nearly 100% in use as farms (U.S. Bur. Census 1983). Douglas County is the only one of the five counties being considered to experience increases in acreage for farms, cropland, and woodland from 1978 to 1982 (see Table 4.9). Land surrounding the mine is privately owned and used by farmers for cropland and pastureland. The land in which the coal mine is located is owned by the Ziegler Coal Company.

4.4.5 Farmland Site (Alternative D)

The 19-ha (47-acre) Alternative D site is located in the north-central portion of Livingston County within a 23.3-km² (9-mi²) quadrant in the southeastern portion of Sunbury Township. Livingston County has over 96% of its land currently in use as farms, although the trend from 1978 to 1982 was toward a decline in acreage for farms, cropland, and woodland (see Table 4.9). The site is privately owned and either in use as cropland or pastureland.

4.5 HISTORICAL AND ARCHEOLOGICAL RESOURCES

4.5.1 West Chicago Site (Proposed Action)

Northeastern Illinois contains a rich and lengthy record of prehistoric and historic settlement. Although the Illinois Historic Preservation Agency does not report any archeological sites at or in close proximity to the West Chicago site, field surveys and test excavations at the nearby Fermi National Accelerator Laboratory uncovered numerous prehistoric remains (Early 1970, 1972; Jeske 1986). A survey of the Kerr-McGee plant site has not been undertaken, however, and would seem to be precluded by health risks (Yingst 1986). Excavation of the contaminated soil at the site might produce subsurface archeological material.

DuPage County possesses a large number of historic structures (e.g., houses, churches, mills, and taverns), several of which are listed in the

National Register of Historic Places (U.S. Dept. Inter. 1980). In addition to one National Register property (McAuley School District No. 27), the West Chicago area contains a number of nineteenth-century buildings (private and public), 10 of which are currently listed in the state register (see Table 4.10).

4.5.2 Active Surface Coal Mine (Alternative A)

The Illinois Historic Preservation Agency has no record of archeological sites in the Rapatee Mine area; however, some data are being collected at the mine and results should be available in the near future (Yingst 1986). Given the distributional pattern of archeological localities in the region and the fact that much of the surface remains to be mined, it is possible that one or more prehistoric sites occur in the area. The Illinois Historic Preservation Agency is reviewing its files on historic structures in the vicinity of Rapatee.

4.5.3 Reclaimed Surface Coal Mine (Alternative B)

Data provided by the Illinois Historic Preservation Agency on archeological sites for the Alternative B site in Peoria County (Table 4.11) are incomplete. Nevertheless, available information shows that numerous archeological sites have been found within and near the boundaries of many mine areas in this part of Illinois, especially those subjected to systematic survey. These sites are chiefly prehistoric surface localities, many of which have probably been destroyed by mining operations since originally reported. As a rule, these sites do not meet eligibility criteria for the National Register (Yingst 1986).

The Illinois Historic Preservation Agency is reviewing its files on historic structures in the vicinity of the site. For proper evaluation, surveys of archeological and historic structures would probably be necessary in areas not subject to previous extensive field examination.

4.5.4 Underground Coal Mine (Alternative C)

No information is available from the Illinois Historic Preservation Agency concerning archeological sites in the vicinity of the Murdock and No. 5 mines in Douglas County; data are being compiled on historic structures (Yingst 1986). No properties are listed in the National Register for this county (U.S. Dept. Inter. 1980).

Table 4.10. Cultural Resources Data, West Chicago

Location	Historic Structure (state no.)	Date of Construction
Neltor and Forest Avenue	Gates House (DU-H-56)	1850s
Main Street and overpass	Railroad marker (DU-H-57)	ca. 1970
131 Ingaltan	House (DU-H-58)	ca. 1890
241 E. Washington	Reed House (DU-H-59)	1865
203 High Street	House (DU-H-60)	ca. 1865
132 Main	West Chicago City Hall (DU-H-61)	1884
216 Arbor	House (DU-H-62)	ca. 1875
Fremont and McConnell	Norris Funeral Home (DU-H-63)	ca. 1890
Washington and Turner Court	Aurora Branch Line Station (DU-H-64)	1893
151 W. Washington	West Chicago Insurance Center (DU-H-65)	ca. 1875

Source: McGimsey et al. (1986).

Table 4.11. Cultural Resources Data, Peoria County

Mine Location	Archeological Sites ^a	Comments
South of Nixon Run, Oakhill Quadrangle	P 54 (outside) P 78 (outside)	Sites are located along Kickapoo Creek, outside mine boundaries.
Southeast of Elmwood, Elmwood Quadrangle	No data	
North of Farmington, Farmington East Quadrangle	No sites recorded	Heavily disturbed area.
North of Hanna City, Hanna City Quadrangle	P 156 (outside) P 157 (outside) P 158 P 159 P 160	P 156 and P 157 are located outside mine boundaries; others that were inside may now be destroyed.

^a Sites are listed in the state register by county (P = Peoria).

Source: Data from Yingst (1986).

4.5.5 Farmland Site (Alternative D)

The Illinois Historic Preservation Agency could not provide information on archeological sites at or near the Alternative D site; data on historic structures are being reviewed (Yingst 1986). No National Register properties are listed in the area, although historic structures are recorded for the towns of Ottawa (LaSalle County) and Pontiac (Livingston County) (U.S. Dept. Inter. 1980). A cultural resources field survey would probably be necessary in order to properly inventory and evaluate the site.

4.6 SOILS AND GEOLOGY

4.6.1 West Chicago Site (Proposed Action)

Nearly 1,200 m (3,900 ft) of early Paleozoic sedimentary rock underlies the West Chicago site (Proposed Action site), ranging in age from Cambrian through Silurian. Overlying the Silurian bedrock is 24 to 27 m (80 to 90 ft) of glacial tills, outwash, and kame deposits. The erosional unconformity between the Silurian bedrock and the surficial glacial deposits represents a time gap of more than 400 million years.

In 1967, the American Potash and Chemical Corporation, which owned the West Chicago site at that time, drilled a deep test well at the site to assess the feasibility of constructing an injection well for deep disposal of liquid wastes. Although the well was never used for liquid waste injection and was eventually plugged, it did yield valuable information concerning the deeper geologic units at the site. In descending order, the deep well penetrated 27.4 m (90 ft) of Pleistocene till, sand, and gravel; 55 m (180 ft) of Silurian dolomite; 26.8 m (88 ft) of Maquoketa (Upper Ordovician) shale and dolomite; 98 m (320 ft) of Galena and Platteville dolomites; 110 m (360 ft) of Glenwood and St. Peter sandstones; and 914 m (3,000 ft) of Cambrian sandstone, siltstone, and dolomite (Figure 4.11). Precambrian granite was encountered at a depth of 1,220 m (4,000 ft).

A water-supply well was drilled at the site by Lindsay Light and Chemical Company (also a former owner of the site) in 1953. The well was 101 m (330 ft) deep and penetrated 27.4 m (90 ft) of Pleistocene glacial till and outwash deposits, 39.6 m (130 ft) of Silurian dolomite, and 32.0 m (105 ft) of argillaceous dolomite and 2.1 m (7.0 ft) of gray shale of the Ordovician Maquoketa Group.

The Silurian and upper Maquoketa dolomites constitute the most heavily used aquifer in DuPage County (Zeizel et al. 1962; Sasman et al. 1981). The Silurian dolomite aquifer is hydraulically connected with overlying glacial sands and gravels and is recharged almost entirely by those units (Zeizel

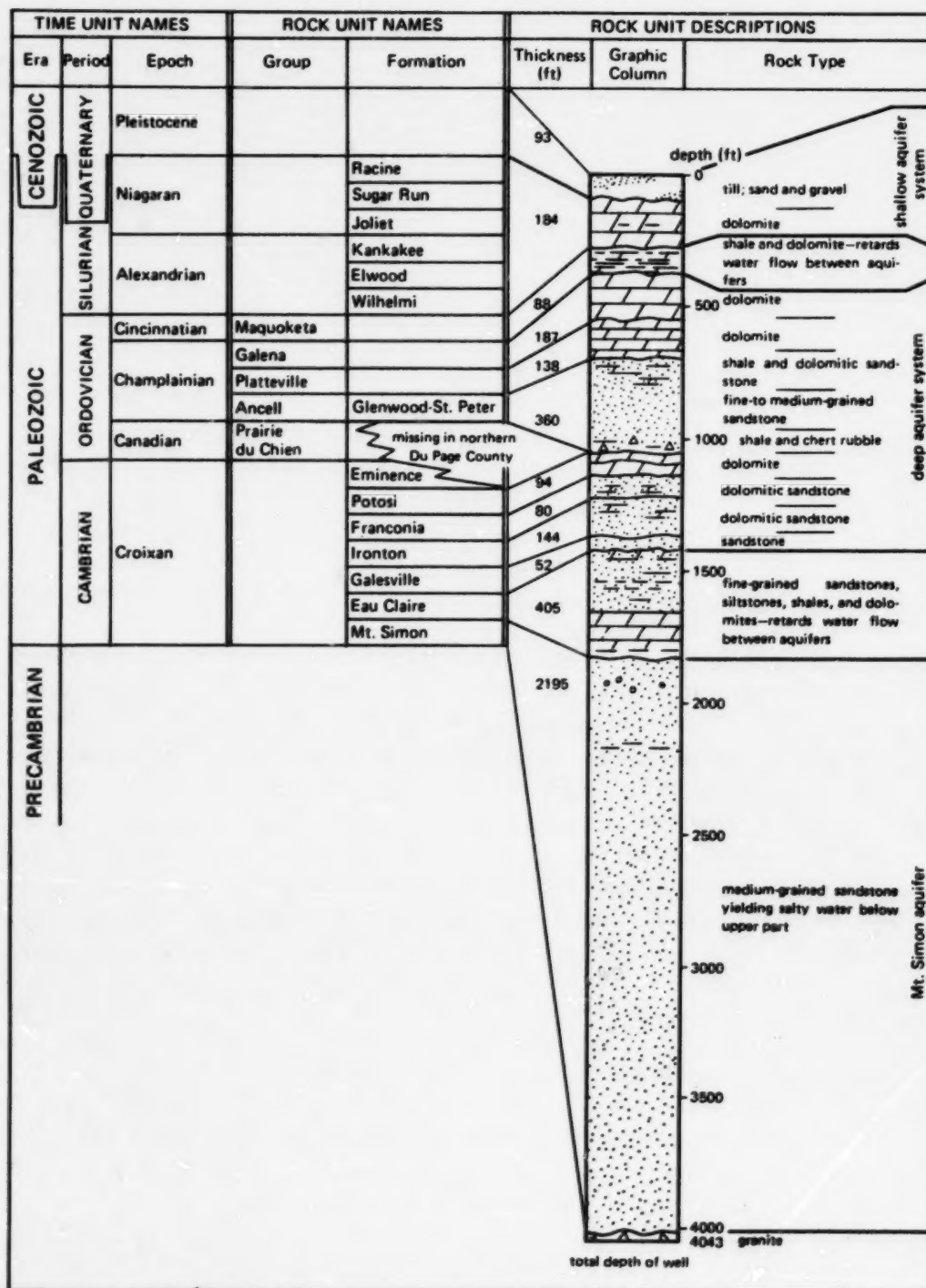


Figure 4.11. Log of Deep Test Well at West Chicago Site (SW1/4 SE1/4 SE1/4, Section 9, T39N, R9E).

Source: Berggren et al. (1978).

et al. 1962). The Maquoketa and Silurian dolomites, however, are separated from lower aquifers by the low-permeability shales of the lower Maquoketa Group.

Since 1976, Kerr-McGee has funded a series of investigations to characterize the shallow subsurface geological, hydrological, geochemical, and radiological conditions at the site (Kerr-McGee 1986). As part of these studies, 362 holes have been drilled to obtain samples and to install monitoring wells (Kerr-McGee 1986--Vol. II). In the fall and early winter of 1985, the Illinois Attorney General's Office sponsored the installation of additional monitoring wells (15 on-site, 1 off-site) in the Pleistocene deposits. Locations of all drill holes are presented in the engineering report of Kerr-McGee (1986--Vol. III).

The bedrock strata, which dip gradually to the east and southeast at about 2 m/km (11 ft/mi), are folded into a series of gentle, low-amplitude anticlines that generally trend east-west. The upper bedrock surface in northwestern DuPage County ranges in elevation from 171 to 210 m (560 to 690 ft) and is composed of Silurian-age dolomites (see Figure 4.12). Generally, the bedrock surface has its highest elevation in western DuPage County. A preglacial drainage divide occurs between West Chicago and Naperville (Figure 4.12). Paleostreams and glaciers eroded down into the Silurian dolomites, thus forming a highly irregular bedrock surface. In the vicinity of West Chicago, the main paleodrainage channel was oriented east-west, with numerous tributary channels angling off in other directions. Because the Silurian dolomites are bounded on the top and bottom by erosional unconformities, their total thickness is irregular, ranging from 40 to 55 m (130 to 180 ft) near West Chicago.

The pre-Pennsylvanian bedrock valleys may significantly affect the direction of groundwater flow in the lower glacial sand and gravel aquifers. Beneath the West Chicago site, the bedrock slopes to the southeast; the groundwater potentiometric surface in the C stratum (middle sand unit) also dips southeast (Kerr-McGee 1986--Vol. II).

During the Pleistocene Epoch, northern Illinois was covered by several advances of continental glaciers. In DuPage County, the eroded Silurian bedrock surface was covered by up to 61 m (200 ft) or more of unconsolidated glacial deposits consisting of a heterogeneous complex of gravel, sand, and clayey silt lenses. Irregular sand and gravel layers were deposited by glacial meltwater along the major drainages and in outwash plains bordering the West Chicago end moraine. Because the glaciers advanced and retreated several times, the outwash deposits were subsequently overridden by the glaciers. Thus, the sand and gravel deposits are interbedded with and

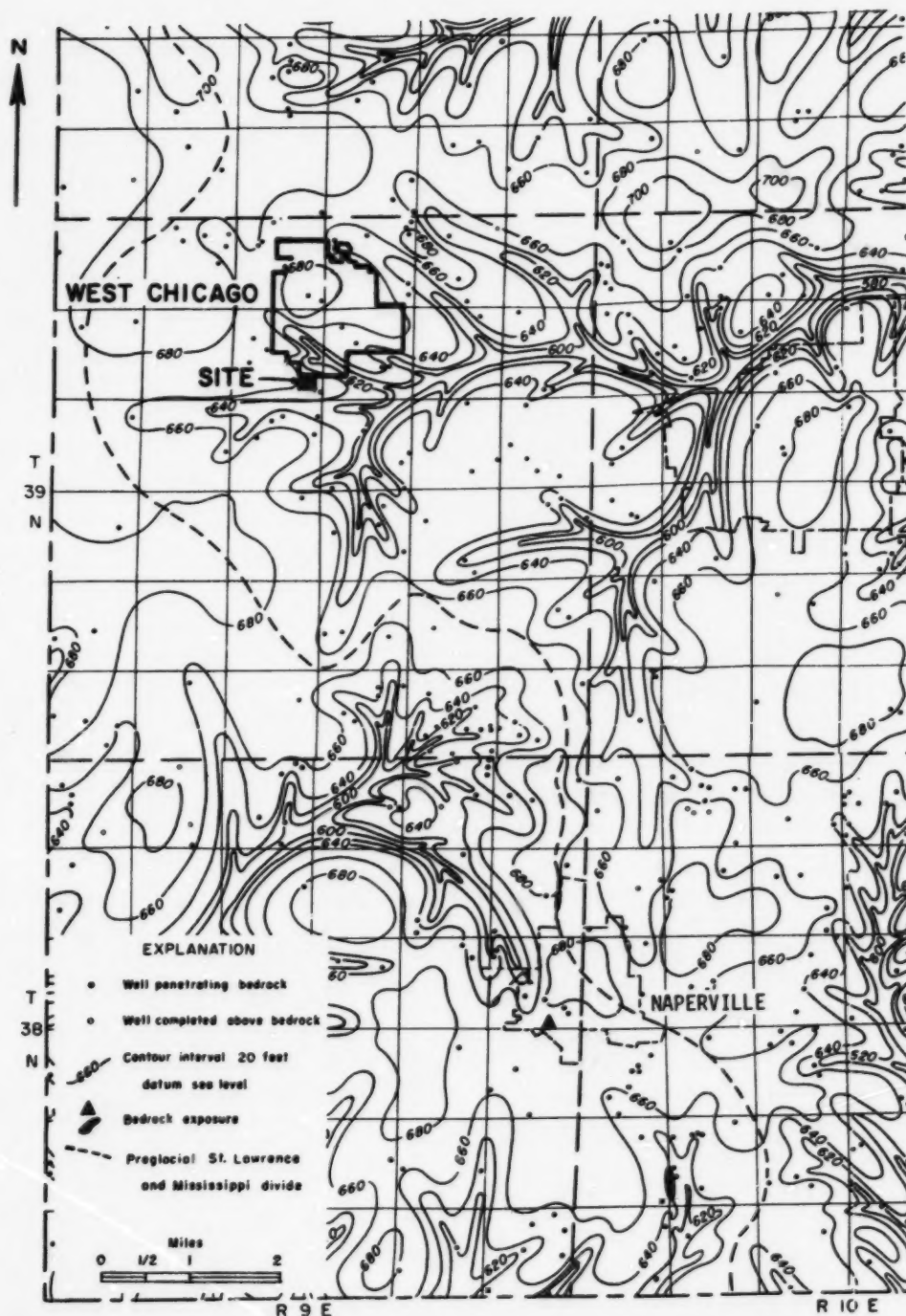


Figure 4.12. Topography of Silurian Bedrock Surface in the West Chicago Region.

Source: Modified from Zeitzel et al. (1962).

interfingering with glacially deposited till units. The tills of the West Chicago area range from a dense silty clay material lacking coarse fragments to a gravelly sandy till closely resembling outwash deposits. In addition, there are thin interbedded units of glaciolacustrine deposits of laminated sandy silt. Most of these sedimentary units -- till, outwash sands and gravels, and lacustrine silts -- are lenticular and discontinuous. However, the extensive drilling conducted at the West Chicago site has resulted in several specific units being identified and traced across the site.

The physical characteristics of the six Pleistocene units identified at the West Chicago site are summarized in Table 4.12. Unit F (uppermost) is a black, brown, and gray clayey silt (windblown loess), with some gravel and sand, that grades upward into an organic-rich topsoil. It ranges in thickness from 0.1 to 2.9 m (0.3 to 9.5 ft). This natural soil unit is missing in many places because of surface construction activities and other alterations. In other places, it is often overlain by artificial fill material or debris.

Underlying Unit F is Unit E, a brown and gray, moderately well sorted, fine- to coarse-grained sand with local gravel intercalations. The thickness of this glacial outwash material averages 3.7 m (12 ft) but is very irregular. It is present everywhere beneath the site and is usually 3 m (10 ft) or thicker. In drill hole B-9, which is outside the southwest site boundary, Unit E is apparently absent. It also thins in the vicinity of ponds 2 and 4. Its greatest thickness is on the southeast side and at the north end of the site, attaining a thickness of more than 4.6 m (15 ft).

Table 4.12. Physical Characteristics of Pleistocene Stratigraphic Units Underlying the West Chicago Site

Stratum	Average Thickness (m)	Thickness Range (m)	Grain-Size Distribution				No. of Samples
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)	
F	0.82	0.12-2.90	6	13	48	33	52
E	3.75 ^a	0.0-13.56 ^a	36	44	16	4	67
D	3.57	0.0-7.71	5	17	49	29	40
C	2.47 ^a	1.8-5.52 ^a	23	51	21	5	22
B	8.05	4.20-12.34	8	32	31	29	46
A	3.32	1.07-5.46	20	56	21	3	19

^a Unit D is absent in the northern end of the site; Units C and E are combined into Unit E at those locations.

Source: Data from Kerr-McGee (1986--Vol. II).

Unit D is a poorly sorted, brown to gray clayey silt till with some sand and gravel. It is thickest on the south side of pond 1 (7.6 m [25 ft]) and thins rapidly to the north, where it is absent, and to the southeast, where it is only 2.9 m (9.5 ft) thick. In the north, where Unit D is absent, Units C and E are combined and undifferentiated.

Unit C is another glacial outwash deposit and consists of brown to gray, moderately well sorted silty sands and gravels. It is present everywhere under the site. Its minimum thickness is about 1.8 m (6.0 ft), and it attains its greatest thickness just northwest of pond 1 and just west of pond 4, where it is about 4.6 to 5.5 m (15 to 18 ft) thick. Because Unit D is absent under the north end of the site, the Unit C and E sands and gravels coalesce. The combined thickness of the two units in this area ranges from about 12.2 to 13.7 m (40 to 45 ft).

Unit B is the lowermost till. It is a gray to blue, clayey, sandy silt. In the lower part of the unit, fine- to coarse-grained clayey sand lenses are present. Based on average values, this unit contains nearly equal amounts of sand, silt, and clay, with minor amounts of gravel (see Table 4.12). Unit B is thickest near pond 4 and the tailings pile, where it reaches a maximum of 12 m (40 ft); it gradually thins to the north, attaining a thickness of 4.3 m (14 ft) at borehole 560 (Figure 4.13).

Unit A, the lowermost glacial deposit, rests on Silurian dolomite. It is a gray to brown, poorly sorted, fine- to coarse-grained silty sand and gravel unit. This glacial outwash deposit is thinnest underneath the tailings pile (1.07 m) and thickens in all directions. It is 5.5 m (18 ft) thick just north of pond 1 and is up to 4.3 m (14 ft) thick in the southeast and southwest corners of the site.

Figure 4.13 is a north-south cross-sectional diagram of the Pleistocene deposits at the West Chicago site. It shows the highly irregular thickness of the individual units; where Unit D is absent around borehole 560, Units C and E merge to form an extra thick sand and gravel layer. Figure 4.14 is an east-west cross-sectional diagram of the Pleistocene deposits. This cross section shows the sand and gravel lenses within the Unit B till and the Unit E sand unit pinching out to the west of the site in borehole B-9.

A soil survey of DuPage County (Mapes 1979) lists the Kerr-McGee site as urban land and does not assign a specific soil name to the site area. However, surrounding areas have been identified as having soils of the Markham-Ashkum or Drummer-Barrington associations. Because so much surface disturbance has occurred at the site, previous studies have not attempted to classify the site soils.

4.6.2 Active Surface Coal Mine (Alternative A)

The Rapatee Mine (Alternative A site), located in the northeast corner of Fulton County, is situated on a principal bedrock ridge (Farmington-Hanna City Ridge), which trends eastward from the mine site toward Peoria (Wanless 1957). The Pennsylvanian bedrock surface ranges in elevation from about 200 to 204 m (655 to 670 ft) at the mine site (Horberg 1957). Overlying the bedrock is a veneer of Pleistocene till and loess approximately 5 to 8 m (15 to 25 ft) thick. Elsewhere in the county, Pleistocene deposits reach thicknesses of about 61 m (200 ft) in buried bedrock valleys (Willman et al. 1967; Lineback 1979).

The upper glacial deposits in the Rapatee Mine area include Wisconsinan-age Peoria Loess, Robein Silt, and Roxana Silt, in descending order. These loess deposits are approximately 3.4 to 4.0 m (11 to 13 ft) thick at the Rapatee Mine (Lineback 1979). Descriptions and analyses of these loess deposits at several locations in Peoria and Fulton counties are presented in Smith (1942), Frye et al. (1962), and Lineback et al. (1979). They are generally composed of 70-90% silt, 10-20% clay, and 0-10% fine sand. Some zones have been leached of all or part of their carbonate minerals, especially calcite, due to weathering. These units exhibit a wide range of clay mineral composition, and expandable clays usually account for 50% or more of the clay minerals (Lineback et al. 1979).

Modern soils have developed on the loess deposits. The different soil units have been characterized, classified, and mapped by Fehrenbacher et al. (1977). In the general vicinity of the Rapatee Mine, the Ipava-Sable soil association is the most prevalent mapping unit in undisturbed areas. This association occurs on the nearly level upland areas (slopes range from 0 to 2%) and generally consists of a dark-colored silty clay loam surface layer, which overlies a light brownish-gray heavy silty clay subsoil. The natural drainage of soils in this association is poor to somewhat poor, and its profile permeability is classified as slow to moderate (Fehrenbacher et al. 1977). The other major soil association found in the mine area is the Keomah-Clinton-Clarksdale. It also occurs on nearly level to gently sloping upland areas. This soil group generally has a light to moderately dark colored silt loam surface layer and a dark yellowish-brown silty clay loam or silty clay subsoil. Other soil associations occur in small areas of the mine permit area, usually on gentle slopes (2-5%). Natural soils were destroyed at older surface mines in the area.

Below the surficial loess deposits and modern soils lies about 4 to 5 m (13 to 15 ft) of glacial tills. Woodfordian (Wisconsinan Stage) glacial advances never reached Fulton County, and the late-Illinoian (Jubilean Substage) glacial advance only reached the far northeastern corner of the

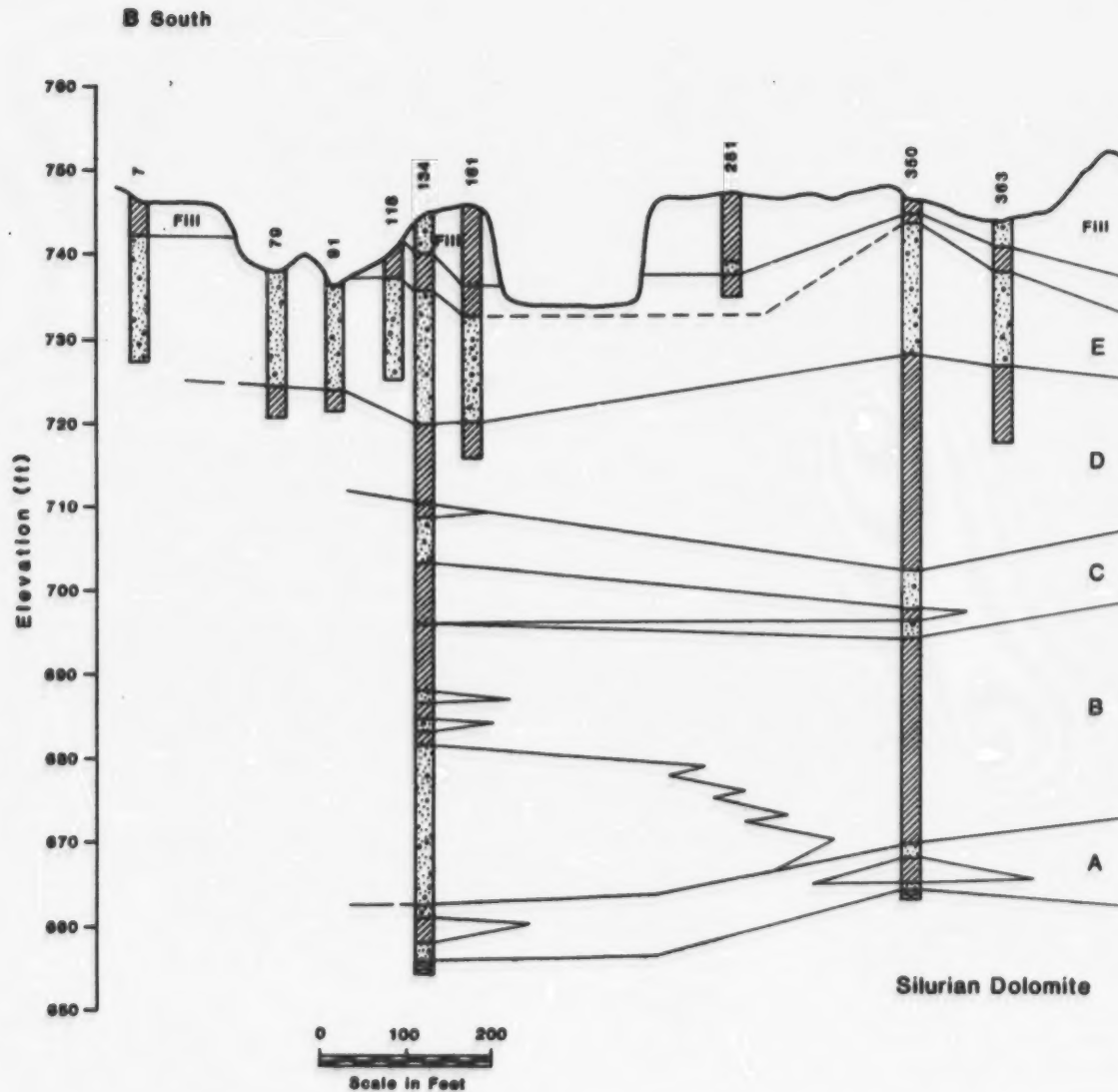
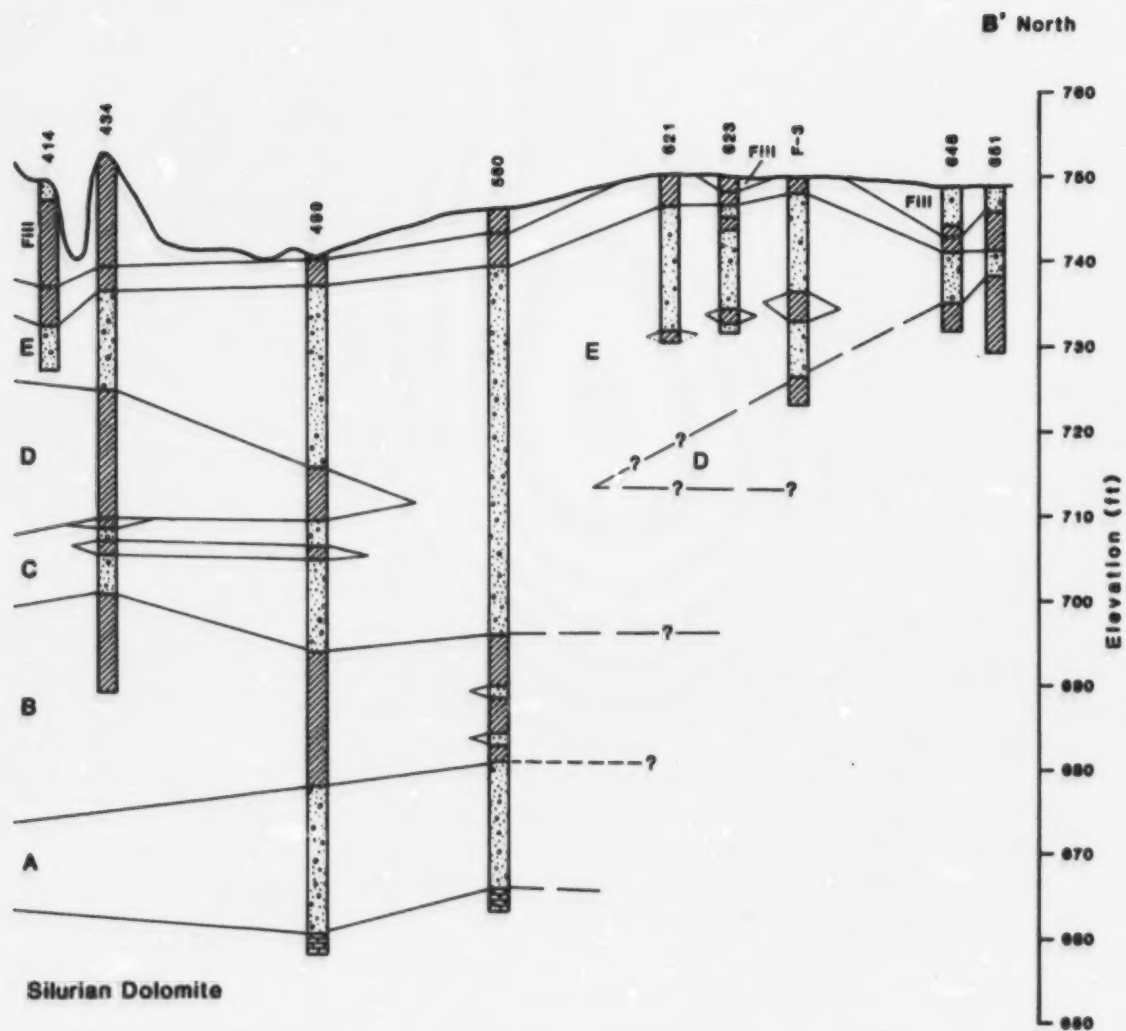


Figure 4.13. North-South Cross Section of Pleistocene Stratigraphic Units, West Chicago Site Area (see Figure 4.14 for legend).

Source: Redrawn from Kerr-McGee (1986--Vol. II).



(Right side of Figure 4.13; see previous page for caption.)

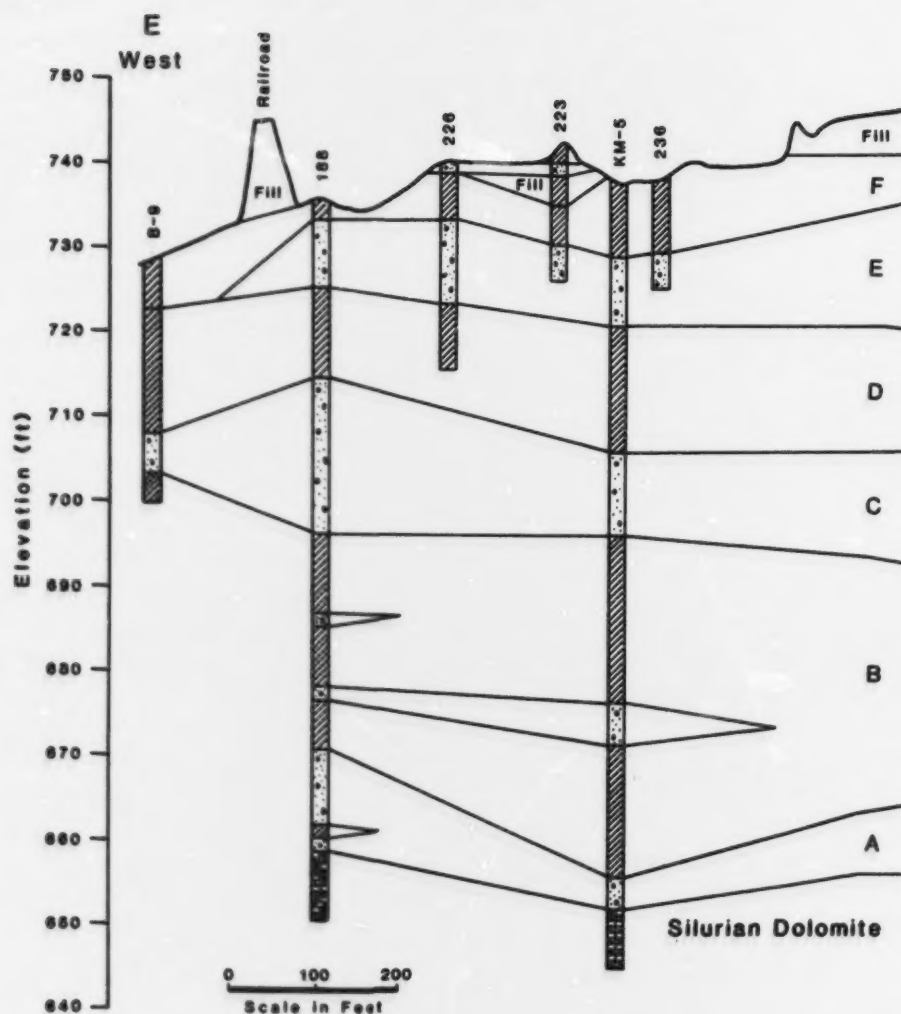
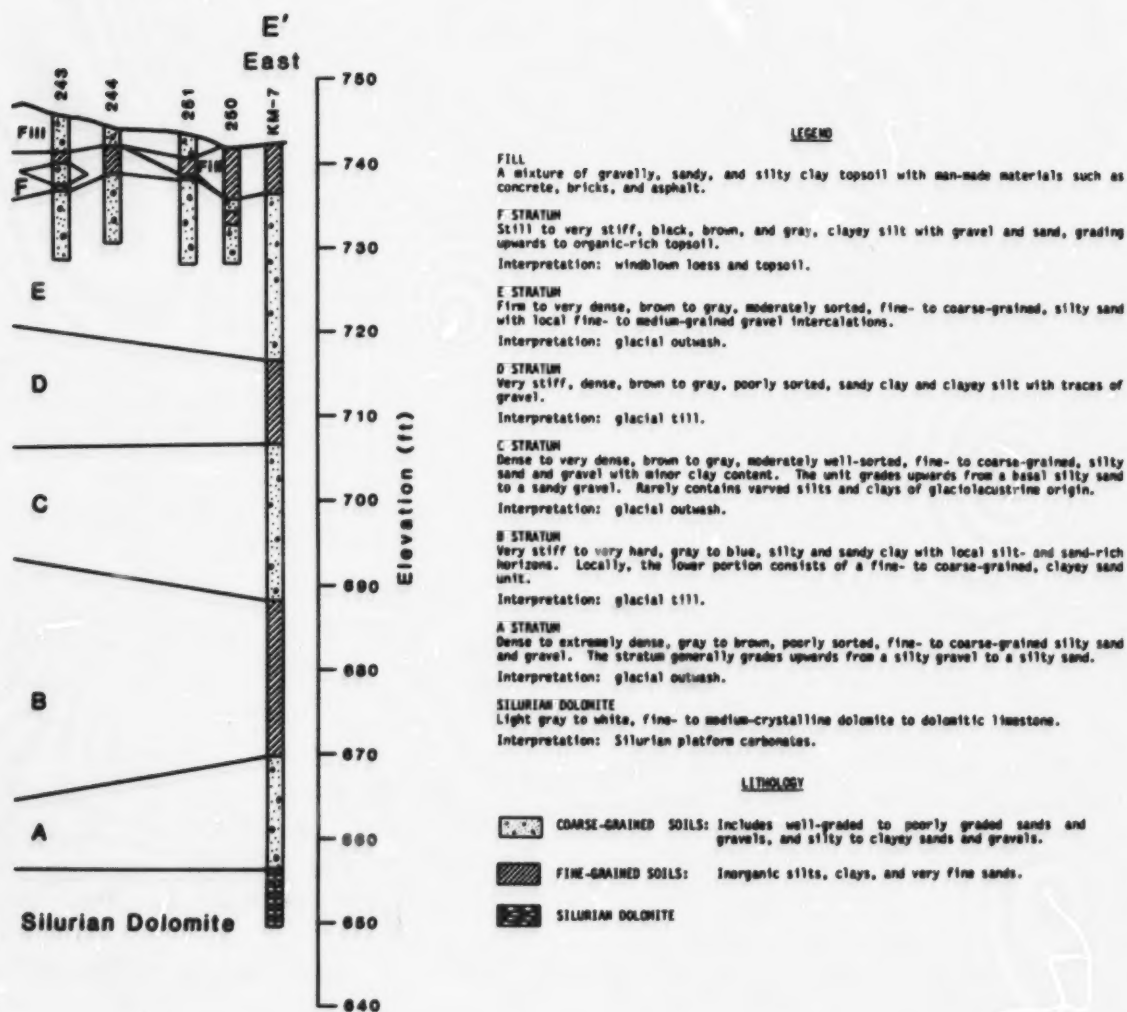


Figure 4.14. East-West Cross Section of Pleistocene Stratigraphic Units, West Chicago Site Area.

Source: Redrawn from Kerr-McGee (1986--Vol. II).



(Right side of Figure 4.14; see previous page for caption.)

county (Lineback 1979). Hence, the youngest glacial till present in most of Fulton County, and at the Rapatee Mine site, is the Hulick Till. Several thin, older Illinoian tills (e.g., Smithboro and Kellerville) and the pre-Illinoian Banner Till are probably present below the Hulick Till. The exact spatial distribution, thickness, and compositional variation of these deeper till units are not completely known (Lineback et al. 1979). Some generalized information on the textural and mineralogic characteristics of each till unit for western Illinois is presented in Table 4.13.

The unconsolidated Pleistocene glacial deposits rest on Pennsylvanian-age bedrock, which contains the major coal seams mined in Illinois. Because of the near-surface coal seams, Fulton County has a long history of surface mining.

Erosion between Pennsylvanian and Quaternary time removed the entire Upper Pennsylvanian McLeansboro Group from the Rapatee Mine area. The Carbondale Formation is the uppermost bedrock unit, and it includes the coal seams mined most extensively in the county -- Colchester No. 2, Springfield No. 5, and Herrin No. 6. Some of the permitted area was previously mined for the Herrin No. 6 Coal. Midland Coal Company is mining parcels of the upper No. 6 Coal that remained after previous shallow surface mining and is also removing the slightly deeper Springfield No. 5 Coal over the entire mine area.

An erosional unconformity separates Pennsylvanian strata from the underlying Burlington and Keokuk limestones of Mississippian age. Both formations are predominantly light gray, white, or buff in color and consist of cherty dolomitic limestones (Wanless 1957; Willman et al. 1975). These two limestones range from 41 to 52 m (135 to 170 ft) thick in the Rapatee Mine area (see Figure 4.15). (The locations of drill holes and the sources of the drill hole data used for Figure 4.15 are presented in Table 4.14.) Groundwater occurs along joints, bedding planes, and solution openings in these two formations, especially in their upper parts. However, high chloride and total solute concentrations usually make this aquifer an unsatisfactory source of water (Horberg et al. 1950).

The Burlington and Keokuk limestones overlie about 70 to 78 m (230 to 255 ft) of the New Albany Shale Group of Late Devonian and Early Mississippian age. This group consists of greenish gray to black, organic-rich dolomitic shales and some silty shales (Willman et al. 1975; Cluff et al. 1981). The New Albany Group is a major aquitard throughout most of Illinois. A structure contour map for the base of the New Albany Group (Cluff et al. 1981) indicates that the strata dip to the east and southeast in the Rapatee Mine area.

Below the New Albany Shale Group lies the Middle Devonian Cedar Valley and Wapsipinicon limestones, which include argillaceous limestones and dolomites. Pyrite and chert are also present in both formations. These

Table 4.13. Textural and Mineralogical Characteristics of Illinoian Till in Western Illinois

Till Member ^a	Textures			Clay Mineralogy			Chittick Carbonate	
	Sand	Silt	Clay	Expand-ables	Illite	Kaolinite plus Chlorite	Calcite	Dolomite
<u>Radnor</u>								
mean	25	49	26	7	73	20	5	19
s.d.	4	-	3	-	5	-	1	2
no.	8	8	8	17	17	17	8	8
<u>Vandalia</u>								
mean	39	40	21	6	74	20	6	25
s.d.	-	-	-	-	-	-	-	-
no.	2	2	2	2	2	2	3	3
<u>Hulick</u>								
mean	26	45	29	10	65	25	5	12
s.d.	8	-	4	-	4	-	1	3
no.	17	17	17	27	27	27	16	16
<u>C</u>								
mean	35	39	26	20	55	25	5	15
s.d.	7	-	6	-	5	-	1	3
no.	21	21	21	45	45	45	17	17
<u>Smithboro</u>								
mean	25	46	29	41	39	20	3	10
s.d.	6	-	2	-	6	-	1	2
no.	17	17	17	26	26	26	16	16
<u>B</u>								
mean	17	56	27	53	29	18	3	10
s.d.	7	-	2	-	5	-	2	1
no.	5	5	5	11	11	11	4	4
<u>A^b</u>		Sandy	-	60-70	20-30	-	3	10
<u>Kellerville^b</u>		Silty	-	40	40	20	3-5	10-15
<u>Pre-Illinoian</u>								
mean	28	37	35	70	14	16	3	4
s.d.	6	-	4	-	4	-	1	1
no.	10	10	10	13	13	13	5	5

^a Mean and standard deviation (s.d.) values are expressed in percent; no. is the number of localities, some of which represent multiple sampling.

^b Sufficient data are not available to provide meaningful averages.

Source: Modified from Lineback et al. (1979).

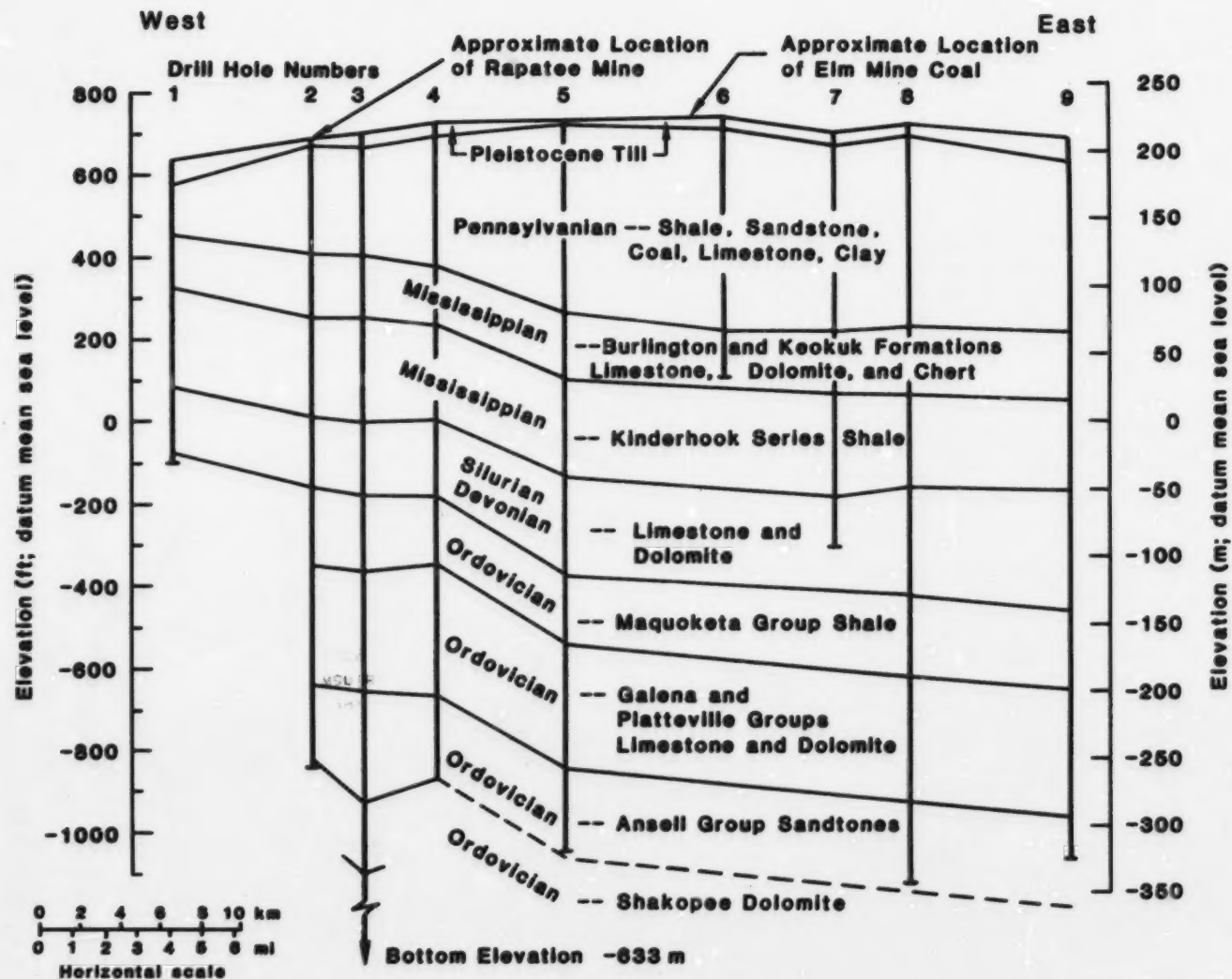


Figure 4.15. East-West Geologic Cross Section through the Rapatee and Elm Mine Areas (locations of drill holes shown in Figures 4.3 and 4.4; sources of drill hole data listed in Table 4.14).

Table 4.14. Location Descriptions and Information Sources for Geologic Drill Holes

Alternative	Figure No. (SES)	Hole No. (SES)	Data Source ^a	Original Hole No.	Location				
					County	Quadrant	Section	Township	Range
A,B	4.15	1	ISGS	Co. No. 22020	Fulton	SW1/4 NE1/4 SW1/4	13	8N	2E
		2	ISGS	Co. No. 1952	Fulton	SW1/4 NW1/4 SW1/4	3	8N	3E
		3	Wanless (1957)	Deep Well No. 2	Fulton	NE1/4 SE1/4 NE1/4	2	8N	3E
		4	ISGS	Co. No. 831	Fulton	SE1/4 NE1/4 SE1/4	6	8N	4E
		5	ISGS	Co. No. 948	Fulton	SE1/4 NE1/4 NE1/4	11	8N	4E
		6	ISGS	Co. No. 1372	Fulton	NW1/4 SE1/4 NE1/4	10	8N	5E
		7	ISGS	Co. No. 165	Peoria	NW1/4 SW1/4 NW1/4	17	8N	6E
		8	Wanless (1957)	Deep Well No. 1	Peoria	NE1/4 SE1/4 NE1/4	10	8N	6E
		9	ISGS	Co. No. 175	Peoria	SW1/4 NE1/4	9	8N	7E
C	4.22	1	ISGS	Co. No. 18	Douglas	NE1/4 NW1/4 SW1/4	34	16N	9E
		2	ISGS	Co. No. 473	Douglas	NE1/4 NE1/4 NE1/4	34	16N	9E
		3	ISGS	Co. No. 19	Douglas	SW1/4 SE1/4 NW1/4	36	16N	9E
		4	ISGS	Co. No. 23	Douglas	NE1/4 NE1/4 NE1/4	28	16N	10E
		5	ISGS	Co. No. 74	Douglas	NE1/4 NE1/4 SE1/4	34	16N	10E
		6	ISGS	Co. No. 21	Douglas	SW1/4 SW1/4 SW1/4	25	16N	10E
		7	ISGS	Co. No. 558	Douglas	SW1/4 SW1/4 SW1/4	30	16N	10E
		8	ISGS	Co. No. 28	Douglas	SE1/4 NE1/4	31	16N	14W
D	4.27	1	ISGS	Co. No. 22451	LaSalle	NW1/4 SE1/4 NE1/4	17	32N	5E
		2	ISGS	Co. No. 22541	LaSalle	NW1/4 NW1/4 NE1/4	34	32N	5E
		3	ISGS	Co. No. 344	LaSalle	NW1/4 SE1/4	16	31N	5E
		4	ISGS	Co. No. 32	Livingston	SE1/4 SE1/4	16	30N	5E
		5	ISGS	Co. No. 398	Livingston	NW1/4 NW1/4 SW1/4	4	29N	5E
		6	ISGS	Co. No. 725	Livingston	SE1/4 SE1/4 SE1/4	8	29N	5E
		7	ISGS	Co. No. 413	Livingston	SW1/4 NE1/4	10	29N	6E
		8	ISGS	Co. No. 39	Livingston	NE1/4 SE1/4 SE1/4	16	30N	6E
		9	ISGS	Co. No. 37	Livingston	SE1/4 SE1/4	3	30N	6E

^a ISGS refers to the drill records kept at the Illinois State Geological Survey, Natural Resources Building, Urbana, Illinois.

limestones are approximately 24 m (80 ft) thick at the Rapatee Mine site (Willman et al. 1975). Because of the shaly character of these limestones, they are not a very permeable aquifer. However, groundwater is present along bedding planes, fractures, and solution openings, and the limestones are hydraulically connected with the underlying Silurian dolomites. The Silurian strata consist of a variety of massive, sandy, silty, and shaly dolomites and dolomitic siltstones. The dolomites are porous and contain significant chert in some areas. The Silurian dolomites are about 30 m (100 ft) thick at the mine site (Willman et al. 1975) and thicken rapidly eastward and northeastward through Peoria County (see Figure 4.15).

Below the Silurian and Devonian carbonate rocks lies the Upper Ordovician Maquoketa Shale Group, another major aquitard in the Illinois Basin. This group consists of dark gray and dark brown shales, with a thin dolomite formation sometimes in the middle (Horberg et al. 1950; Wanless 1957; Willman et al. 1975). The Maquoketa Shale Group ranges from 49 to 58 m (160 to 190 ft) thick in the vicinity of the Rapatee Mine.

Below the Maquoketa Shale Group are the Middle Ordovician Galena and Platteville groups. The rocks are predominantly massive, partly vesicular dolomite in the upper section and darker, finer-grained dolomite with some chert beds and occasional thin shale partings in the lower part (Horberg et al. 1950; Willman et al. 1975). The approximate thickness of the Galena-Platteville dolomites in the vicinity of the Rapatee Mine is 88 m (290 ft); in the northeastern corner of Fulton County, these dolomites range from 72 to 102 m (235 to 335 ft) thick (see Figure 4.15). Groundwater in the Galena and Platteville groups occurs mostly along bedding planes, fractures, and solution cavities. Potential well yields are highly variable and depend on the degree of fracturing and the development of solution cavities. Crevices in the dolomite have been reported in one water well near Peoria and a deeper well in the town of Wyoming in Stark County (Horberg et al. 1950).

Most water supplies for towns and industry in the northeast corner of Fulton County are obtained from deep wells in the Glenwood-St. Peter sandstones (Ansell Group, Middle Ordovician), which lie directly below the Galena-Platteville dolomites. St. Peter Sandstone is white, well sorted, medium grained, and poorly cemented. The Glenwood Formation, located above the St. Peter, also contains sandstone but includes some beds of green shale and impure dolomite (Horberg et al. 1950; Wanless 1957; Willman et al. 1975). Together, these sandstone formations are about 61 to 79 m (200 to 260 ft) thick in the Rapatee Mine area.

A deep well drilled in 1933 provides drinking water for the Rapatee Mine and makeup water for the coal-washing plant. The well penetrated an additional 350 m (1,150 ft) of Ordovician and Cambrian dolomites and

sandstones below the St. Peter Sandstone. Geologic units below the St. Peter Sandstone are described in Horberg et al. (1950--p. 18). The deepest formation penetrated by the well was the Cambrian Galesville Sandstone; the Galesville Sandstone and the creviced upper part of the Trempealeau and the lower part of the Oneota dolomites were very permeable.

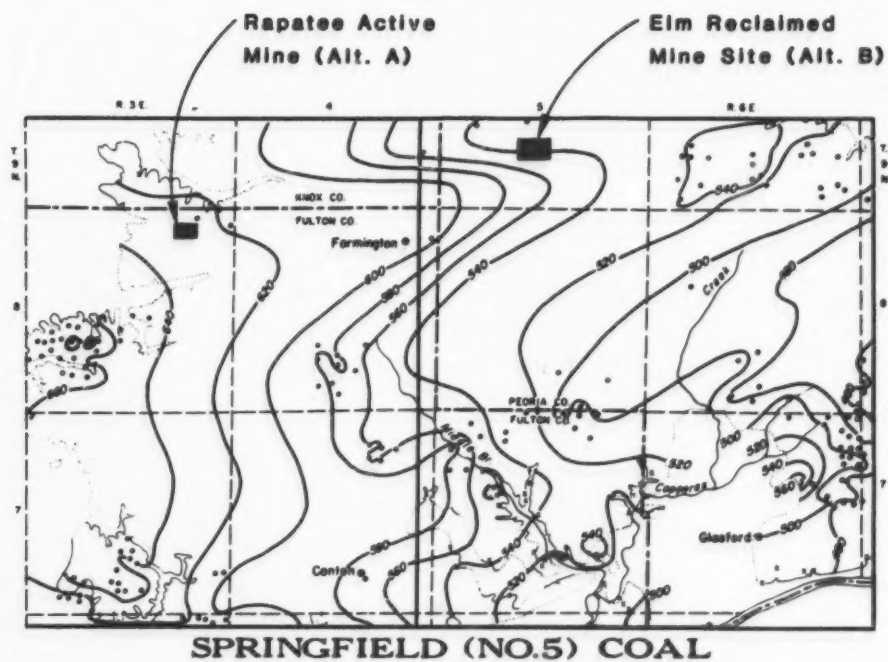
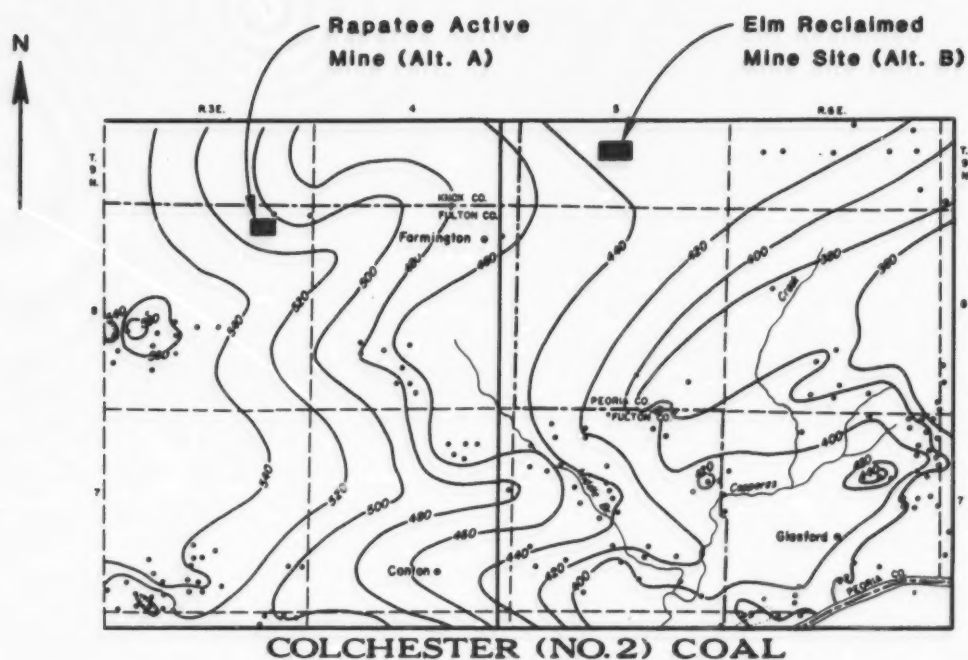
The Cambrian System rocks in northeastern Fulton County are estimated to be about 670 to 700 m (2,200 to 2,300 ft) thick (Willman et al. 1975--Fig. C.2). The Midland Coal Company deep well penetrated only 172 m (565 ft) of the Cambrian System. Therefore, approximately 488 to 518 m (1,600 to 1,700 ft) of Cambrian rock lies below the Galesville Sandstone, including about 100 m (330 ft) of the Eau Claire Formation (mostly siltstone, shale, and dolomite) and 366 to 427 m (1,200 to 1,400 ft) of the Mt. Simon Sandstone, which represents the base of the Cambrian System (Willman et al. 1975).

Fulton County lies on the northwest edge of the Illinois Basin. The deepest part of this structural basin lies in far southeastern Illinois; therefore, rock units in Peoria County generally dip to the southeast toward the basin's center. This regional dip is well illustrated for the top of the New Albany Shale Group (Wanless 1957--Fig. 63), the base of the New Albany Group (Cluff et al. 1981--Plate 4), and the top of the Galena Group (Willman et al. 1975--Fig. 0-3).

Pennsylvanian structures differ somewhat from those in pre-Pennsylvanian rocks because of late Mississippian and early Pennsylvanian tectonic movements and the pre-Pennsylvanian erosional surface. The base of the Pennsylvanian rocks is at an elevation of about 183 m (600 ft) in Warren County on the northwest side of Fulton County and at an elevation of about 30 m (100 ft) at Pekin in Tazewell County on the east side of Fulton County (Wanless 1957--Fig. 23), which equates to an average eastward regional dip of 2 m/km (11 ft/mi). This regional dip is modified by relatively small anticlines and synclines whose axes generally trend eastward or northeastward and plunge gently eastward toward the basin (Wanless 1957). Structural contour maps for the Colchester No. 2 and Springfield No. 5 coals are presented in Figure 4.16. The Rapatee Mine lies on the northwest limb of the northeast-plunging Farmington anticline. At this location, the No. 5 Coal and adjacent strata dip northeastward at about 1.6 m/km.

4.6.3 Reclaimed Surface Coal Mine (Alternative B)

The Elm Mine (Alternative B site) was a surface coal mine operated by Peabody Coal Company from 1968 to 1970 and Midland Coal Company from 1970 to 1984. Most of the mined areas have been graded relatively flat, covered with topsoil, and revegetated to pasture grasses. Some pits were left open and allowed to fill with water and become lakes.



SCALE
0 1 2 3 4 5 6 7 8 9 10

Figure 4.16. Structural Contour Maps of the Colchester No. 2 and Springfield No. 5 Coals.

Source: Modified from Wanless (1957).

The characteristics of geologic units in this mine area are very similar to those described in Section 4.6.2 (see Figure 4.15). Like the Rapatee Mine area, the uppermost geologic deposits of western Peoria County are Wisconsinan-age loess deposits, which are approximately 3.7 to 4.3 m (12 to 14 ft) thick around the Elm Mine (Lineback et al. 1979). The textural and mineralogic characteristics of the loess deposits are the same as those summarized in Section 4.6.2.

The Wisconsinan (Woodfordian Substage) glacial advance never reached western Peoria County (Horberg et al. 1950; Willman and Frye 1970). Unlike the Rapatee Mine site, however, the Jubileean Substage (upper Illinoian) glacial advance did reach the Elm Mine area and deposited the Radnor Till Member of the Glasford Formation (Willman and Frye 1970; Lineback 1979; Lineback et al. 1979). This uppermost till unit is characterized as gray, compact, and silty, and it has a high illite clay content (see Table 4.12). Its general textural and mineralogic characteristics are discussed in greater detail in Willman and Frye (1970) and Lineback et al. (1979).

Underlying the Radnor Till in western Peoria County is another glacial deposit, the Toulon Member of the Glasford Formation, that is absent at the Rapatee Mine in Fulton County. Almost 26 km (16 mi) northeast of the Elm Mine, it consists of 3.0 m (10 ft) of irregularly bedded sand, silt, and sandy silt occupying a paleochannel cut in the Hulick Till (Willman and Frye 1970; Lineback et al. 1979). About 26 km (16 mi) southeast of the mine site, however, the Toulon Member is only 61 cm (24 in.) thick and consists mostly of silt with some sand (Lineback et al. 1979). Its distribution and thickness are highly variable, which is characteristic of glacial outwash deposits.

Below the Toulon Member are other Illinoian glacial tills similar to those found at the Rapatee Mine (see Section 4.6.2). The total thickness of glacial deposits at the Elm Mine averages 9.1 m (30 ft) -- about 4.0 m (13 ft) of loess and 5.8 m (19 ft) of underlying tills.

The total thickness of Pennsylvanian-age rock in the Elm Mine area is about 122 m (400 ft), and the base elevation of the Pennsylvanian System is about 85 m (280 ft) (Wanless 1957). Below the Pennsylvanian strata lies about 30 m (100 ft) of Mississippian Burlington Limestone (Keokuk Limestone is absent due to pre-Pennsylvanian erosion [Horberg et al. 1950; Wanless 1957]), 73 m (240 ft) of the New Albany Shale Group, 70 m (230 ft) of Silurian and Devonian dolomites, 49 m (160 ft) of the Maquoketa Shale Group, 100 m (330 ft) of the Galena and Platteville groups, and 61 m (200 ft) of Glenwood and St. Peter sandstones. The thicknesses of these geologic units have been estimated by interpolating thicknesses in surrounding deep wells and isopach maps presented in Horberg et al. (1950), Wanless (1957), and Willman et al.

(1975). The geologic units below the St. Peter Sandstone are probably similar in thickness and characteristics to those described in Section 4.6.2.

The Elm Mine lies on the north limb of the Farmington anticline, which plunges slightly to the east-northeast (see Figure 4.16). The Elmwood syncline is north of and parallel to the Farmington anticline. Northward from the northeast corner of Fulton County, the Springfield No. 5 Coal drops from an elevation of about 183 m (600 ft) on the Farmington anticlinal axis to about 168 m (550 ft) on the Elmwood synclinal axis, which equates to a northward dip of 5.3 m/km (28 ft/mi). Pre-Pennsylvanian strata generally dip eastward or southeastward toward the center of the Illinois Basin (see Section 4.6.2).

4.6.4 Underground Coal Mine (Alternative C)

Structural geologic features and pre-Pleistocene erosion of the bedrock surface are important geologic factors influencing the spatial distribution and thicknesses of lithologic units at the Alternative C site. The LaSalle anticlinal belt is a major bedrock fold in Illinois that trends north-south through Douglas County on the west side of the Embarras River (see Figure 4.17). Treworgy (1981) designates the anticlinal belt as the Tuscola anticline in this area, which also includes the Hayes and Shaw domes along its axis (Figure 4.18). The generalized east-west cross section presented in Figure 4.19 shows the anticline in the center of Douglas County. The Murdock syncline is a gentler bedrock fold that lies to the east of the LaSalle (Tuscola) anticline and also trends approximately north-south (Figure 4.18). The axis of the Murdock syncline runs directly through the middle of the Murdock and No. 5 underground mines. In general, the Herrin No. 6 Coal dips toward the center of the two mines and to the south-southwest, the direction in which the syncline is plunging.

The other major geologic features of east-central Illinois are the deep bedrock valleys that were eroded by post-Pennsylvanian streams (Selkregg and Kempton 1958; Stephenson 1967; Visocky and Schicht 1969; Poole and Heigold 1981; Kempton et al. 1981, 1982). The major paleostream was the Teays-Mahomet, which flowed from west to east and entered the ancient Mississippi River in Tazewell County (see Figure 4.17). The main branch of the Pesotum valley runs from east to west along the northern boundary of Douglas County and enters the Mahomet valley to the northwest in Piatt County. Several paleostreams that were tributaries to the Pesotum valley eroded through bedrock in Douglas County. The resulting bedrock topography is shown in Figure 4.20. The underground mines are located on the bedrock high in west-central Douglas County. On the north and east sides of the No. 5 Mine, the

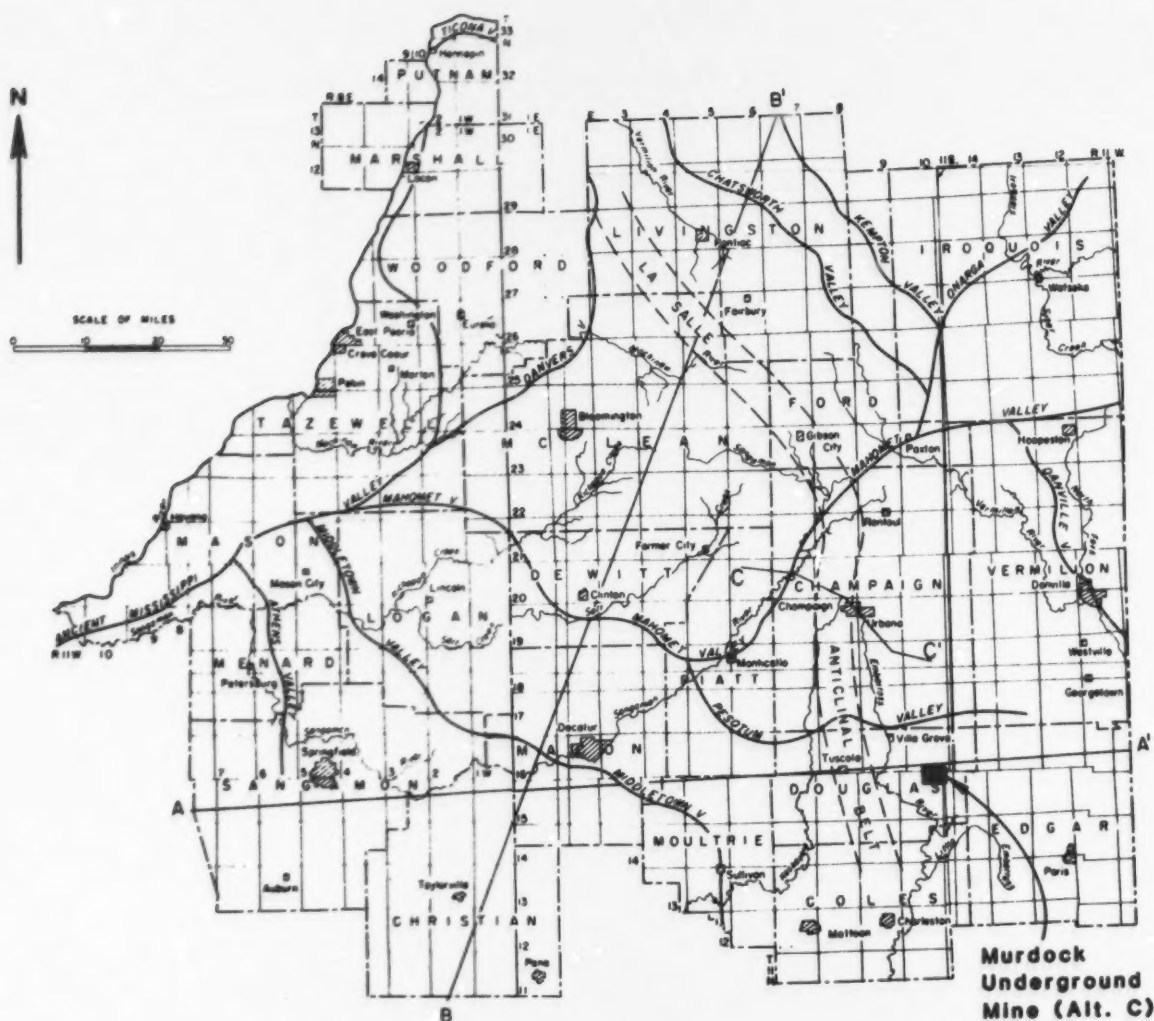


Figure 4.17. Major Bedrock Valleys and the LaSalle Anticlinal Belt in East-Central Illinois.

Source: Modified from Selkregg and Kempton (1958).

valley floor is at an elevation of approximately 134 to 140 m (440 to 460 ft). On the west side of the mines, the bedrock valley reaches a minimum elevation of about 149 m (490 ft).

Several glacial advances and retreats through east-central Illinois during the Pleistocene Epoch caused these bedrock valleys to be completely or nearly completely filled with several layers of till, outwash sands and

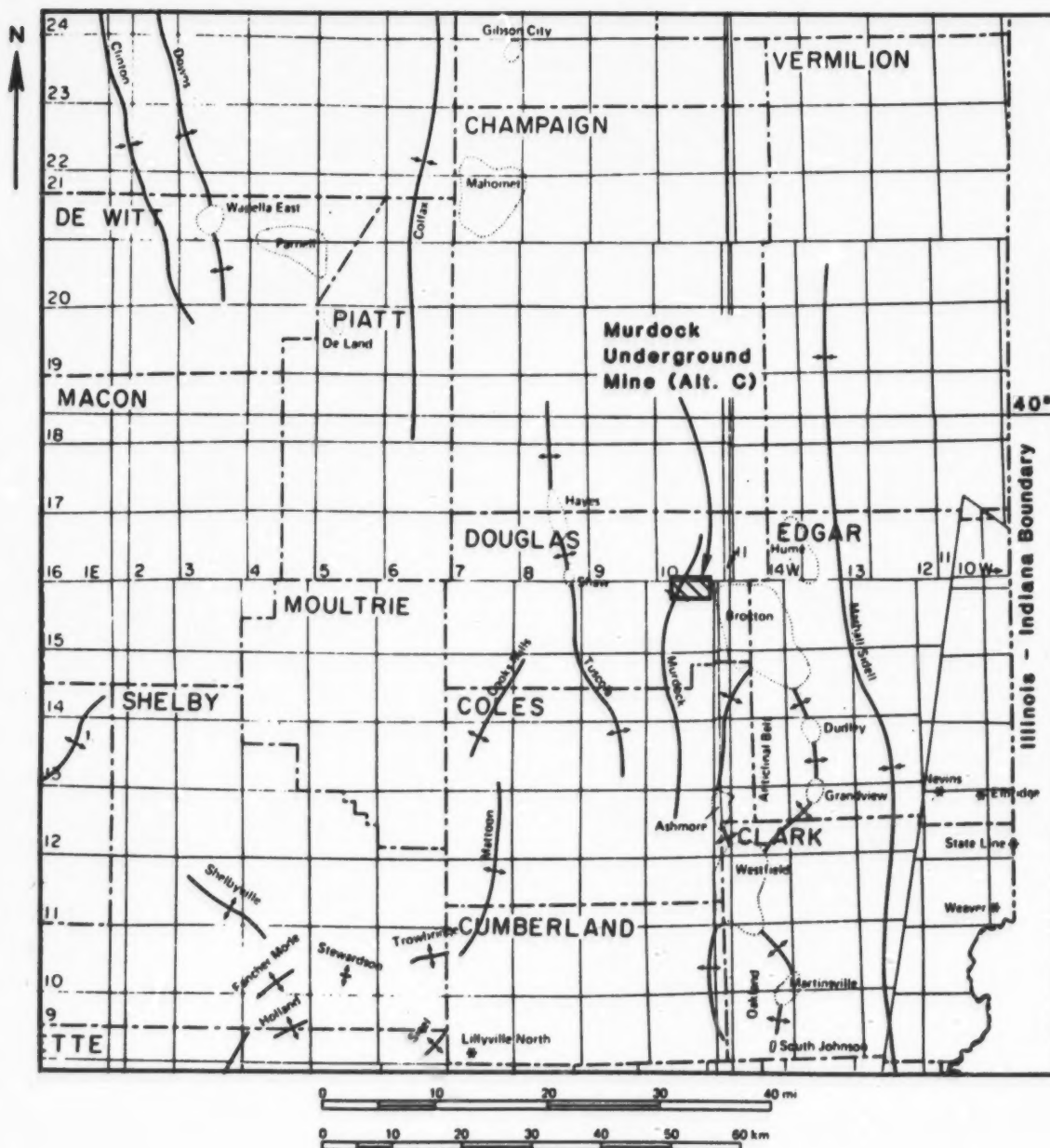


Figure 4.18. Structural Geologic Features in Douglas and Surrounding Counties.

Source: Modified from Treworgy (1981).

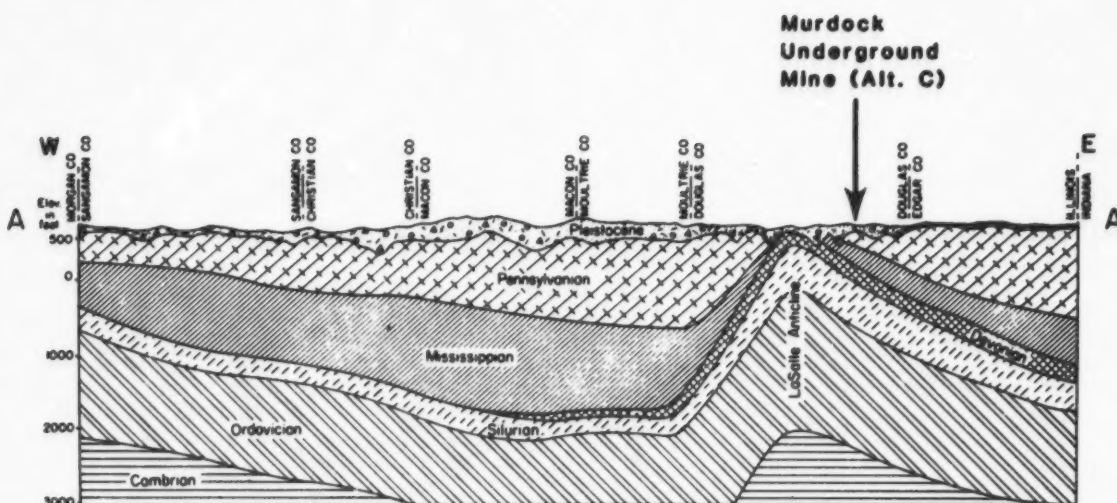


Figure 4.19. East-West Geologic Cross Section through East-Central Illinois (line of section shown in Figure 4.17).

Source: Modified from Selkregg and Kempton (1958).

gravels, and lake deposits. In most cases, the bedrock valleys do not coincide with modern-day surface streams (see Figure 4.17).

East-west cross sections of Pleistocene deposits north of the No. 5 Mine and south of the Murdock Mine are shown in Figure 4.21. The pre-Illinoian Banner Till Formation forms the lower half of the deposits and fills the bedrock valleys. In the Mahomet bedrock valley, the lowermost Mahomet Sand Member consists of clean sand and gravel and is usually more than 46 m (150 ft) thick. This unit is the most significant aquifer in east-central Illinois. However, the "bedrock valleys tributary to the Mahomet valley, including the Pesotum valley, do not appear to contain significant sand and gravel aquifers related to the Mahomet Sand. Rather, these valleys contain fine-textured sediments deposited in lakes ponded by the aggrading outwash, which blocked their confluence with the Mahomet valley" (Kempton et al. 1982).

The Banner Till is up to 49 m (160 ft) thick in the Pesotum valley system and thins to 0 m over some of the bedrock highs (see Figure 4.21). Overlying the Banner Till in the Alternative C area is 3 to 37 m (10 to 120 ft) of Illinoian Glasford tills. Sand and gravel aquifers are common in the Glasford Formation in east-central Illinois, particularly at the base of the formation. However, no significant Glasford sand or gravel units have been located in eastern Douglas County (Kempton et al. 1982).

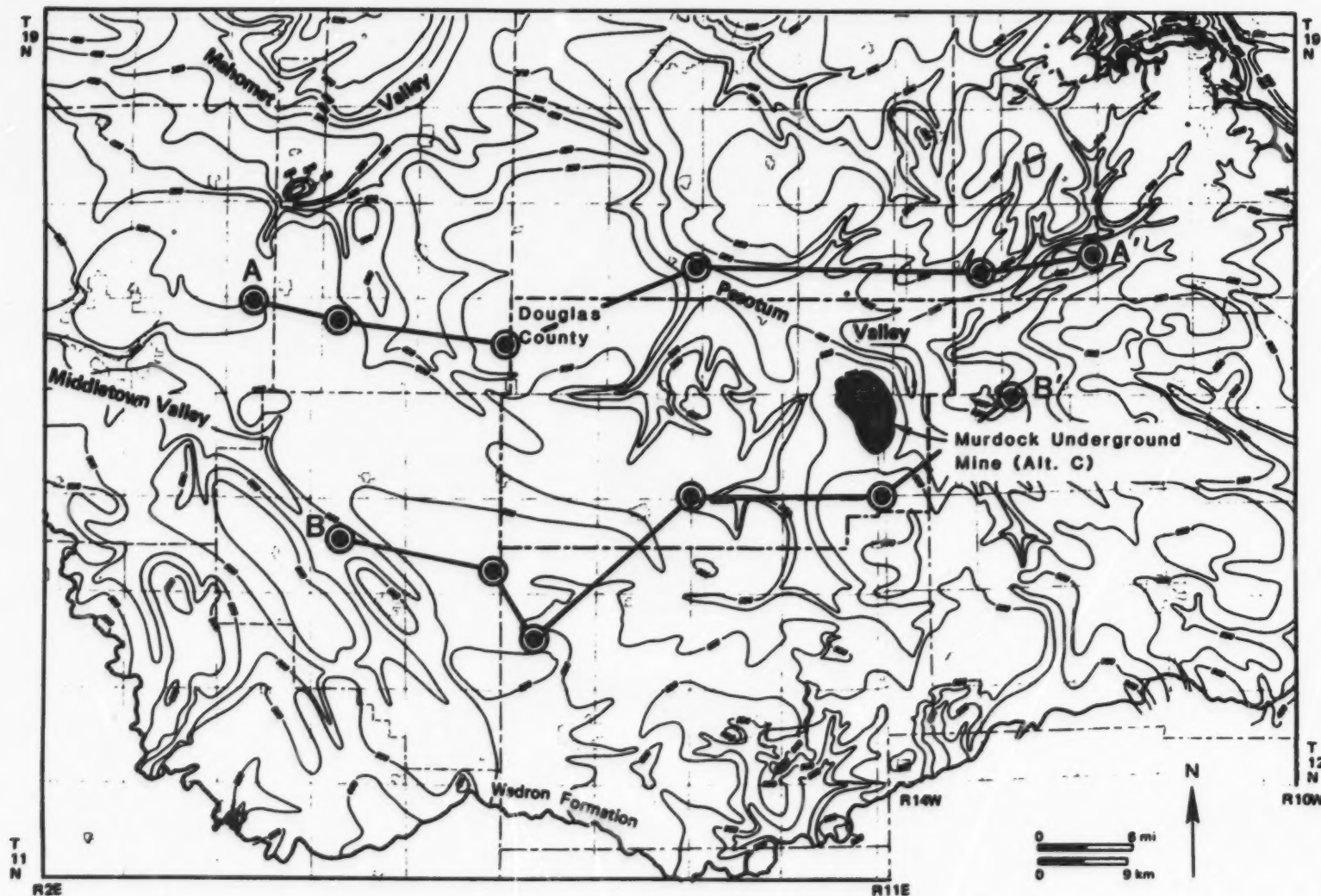


Figure 4.20. Bedrock Topography in East-Central Illinois.
Source: Modified from Kempton et al. (1982).

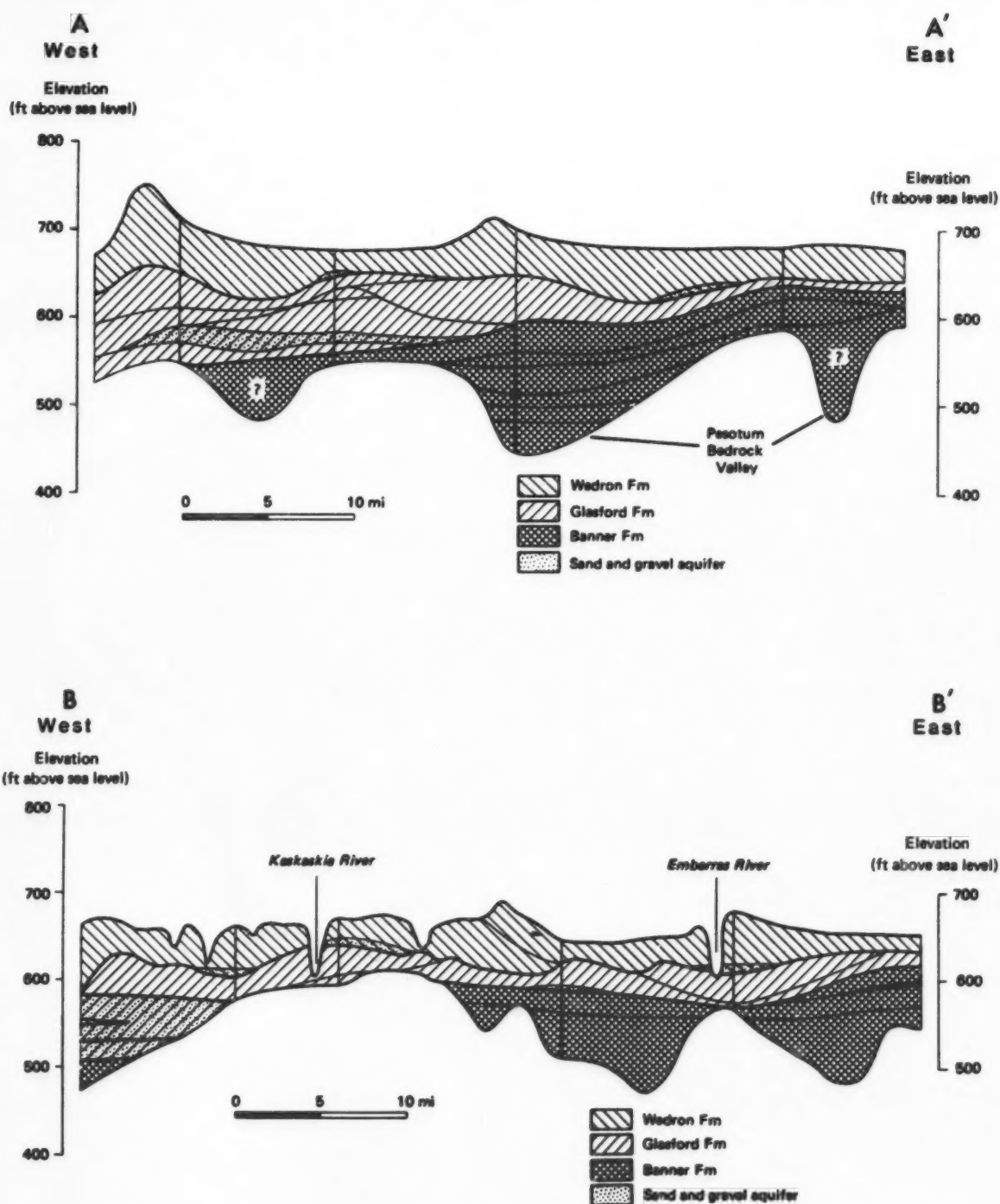


Figure 4.21. East-West Cross Sections of Pleistocene Deposits in East-Central Illinois (lines of section shown in Figure 4.20).

Source: Modified from Kempton et al. (1982).

Overlying the Banner Till is up to 20 m (65 ft) of the Wisconsin Wedron Formation. At scattered locations in east-central Illinois, the Ashmore aquifer is situated at the base of the Wedron Formation. One of these locations is in the north part of T16N, R10E, which overlies part of the No. 5 Mine (Kempton et al. 1982). The Ashmore aquifer is a tabular outwash sand and gravel, averaging about 3 m (10 ft) thick. In most of east-central Illinois, however, the Ashmore sand is absent, and the Wedron Formation consists entirely of clayey till deposits (Kempton et al. 1982). The Ashmore Sand does not occur over the Murdock Mine (Kempton et al. 1982).

Drill records and water well records of the Illinois State Geological Survey for T15N, R10E and R11E, show that there are only thin discontinuous lenses of sand and gravel in the glacial deposits above the Murdock Mine (not including the Brushy Creek alluvium). Most of the Pleistocene materials are tills of three different formations. General grain-size distributions, clay mineral content, and carbonate content in unweathered tills of east-central Illinois are given in Table 4.15. Overall, these tills are composed of 38-55% silt, 19-36% clay, and 18-40% sand. Illite is the predominant clay mineral; kaolinite plus chlorite is generally the second most abundant clay group (Johnson et al. 1972).

After the upper till unit (Batestown Till of the Wedron Formation) was deposited and the glacier retreated from Douglas County, a lake formed in a basin between the Arcola moraine to the south and the West Ridge and Pesotum moraines to the north. This glacial Lake Douglas filled with water from the glacial Embarras River, which entered the basin through a gap in the two northern moraines. Lake Douglas was about 48 km (30 mi) in an east-west direction and 13 km (8 mi) in a north-south direction, and had a total area of 311 km² (120 mi²) (Gardiner et al. 1966; Fraser and Steinmetz 1971). More than 3 m (10 ft) of sand (Equality Formation, Dolton Member) was deposited in a lobate alluvial delta deposit where the Embarras River entered Lake Douglas to the west of the mine site in T15N, R9E. Up to 4 m (13 ft) of silt and clay lenses (Equality Formation, Carmi Member) was deposited in the remainder of the former lake, which includes most of the land area overlying the underground mines. The former lake basin is now a nearly level, poorly drained plain at an approximate elevation of 195 m (640 ft) (Gardiner et al. 1966; Fraser and Steinmetz 1971).

The Wisconsin-age Richland Loess is the uppermost stratigraphic unit over most of Douglas County. Its thickness ranges from 38 cm (15 in.) on morainal ridges to 140 cm (55 in.) in the northwestern part of the county. This aeolian deposit of silt and clay is 76 to 122 cm (30 to 48 in.) thick over the glacial Lake Douglas silty clays in the area of the mines (Hallbick and Fehrenbacher 1971).

Table 4.15. Percent Distribution of Clastics, Clay Minerals, and Carbonates in Unweathered Till of East-Central Illinois

Till Member ^a	Clastics (<2 mm)			Clay Minerals (<2 μ m)			Carbonates (<74 μ m)		
	Sand	Silt	Clay	Expandable Clay Minerals	Illite	Kaolinite plus Chlorite	Calcite	Dolomite	Total Carbonate
<u>Snider</u>									
mean	15	47	38	3	83	14	6	17	23
s.d.	6	5	8	1	3	3	1	1	1
no.	18	18	18	18	18	18	18	18	18
<u>Batestown</u>									
mean	28	38	34	3	79	18	5	19	24
s.d.	3	3	4	1	4	4	1	2	2
no.	23	23	23	24	24	24	24	24	24
<u>Glenburn</u>									
mean	34	42	25	13	64	24	5	18	23
s.d.	5	6	5	4	5	3	2	2	4
no.	30	30	30	25	25	25	30	30	30
<u>Oakland</u>									
mean	18	46	36	22	53	25	3	11	14
s.d.	13	9	5	7	5	3	1	2	2
no.	9	9	9	9	9	9	9	9	9
<u>Radnor</u>									
mean	40	41	19	7	75	19	5	26	31
s.d.	5	2	5	3	6	5	1	3	4
no.	11	11	11	11	11	11	10	10	10
<u>Vandalia</u>									
mean	39	41	20	19	63	18	9	20	29
s.d.	7	7	4	11	11	4	2	4	5
no.	49	49	49	46	46	46	38	38	38

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Table 4.15. Continued

Till Member ^a	Clastics (<2 mm)			Clay Minerals (<2 μ m)			Carbonates (<74 μ m)		Total Carbonate
	Sand	Silt	Clay	Expandable Clay Minerals	Illite	Kaolinite plus Chlorite	Calcite	Dolomite	
<u>Smithboro</u>									
mean	20	55	26	35	46	19	4	16	20
s.d.	6	8	4	13	12	3	1	3	4
no.	11	11	11	10	10	10	10	10	10
<u>Tilton</u>									
mean	37	40	23	15	65	20	12	18	30
s.d.	5	7	4	5	6	2	2	2	4
no.	12	12	12	12	12	12	9	9	9
<u>Hillery</u>									
mean	31	41	29	8	71	22	13	13	26
s.d.	4	1	4	6	2	4	2	2	1
no.	4	4	4	4	4	4	4	4	4
<u>Harmattan</u>									
mean	25	42	33	16	62	22	7	16	23
s.d.	6	10	5	10	8	3	2	5	6
no.	5	5	5	5	5	5	5	5	5
<u>Hegeler</u>									
mean	20	51	29	33	27	40	0.2	0.4	0.6
s.d.	5	5	5	4	3	4	0.2	0.2	0.4
no.	9	9	9	9	9	9	9	9	9

^a Mean and standard deviation (s.d.) values are expressed in percent; no. is the number of localities, some of which represent multiple sampling.

Source: Johnson et al. (1972); data for the Hegeler Till Member are from Johnson (1971).

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Other surficial geologic deposits include relatively narrow deposits of sand and gravel along many of the current stream valleys. These alluvial deposits are mainly of Wisconsinan age (Henry Formation), but some may be of late Wisconsinan age (Holocene Cahokia Alluvium) (Kempton et al. 1982). In the vicinity of the underground mines, these surficial sands and gravels are found only along the primary valleys of the Embarras River and Brushy Fork.

The major surficial soil associations mapped in Douglas County have developed in loess over silty clay till; loess over silty, clayey lake deposits; or loess over glacial outwash (Hallbick and Fehrenbacher 1971). Most of the surface soils overlying the underground mine have been mapped as belonging to the Milford-Drummer-Flanigan association. These very poorly to somewhat poorly drained, nearly level soils formed in 76 to 122 cm (30 to 48 in.) of silty loess material overlying glacial lakebed deposits. This association covers 21% of the county. About 50% of the soil association area consists of the Milford soil, which has a surface and a subsoil composed of heavy silty clay loam or silty clay (Hallbick and Fehrenbacher 1971). The Milford and Drummer soils are generally wet unless they are artificially drained. The area overlying the underground mines has few natural drainage channels; deep drainage ditches have commonly been dug to supply outlets for tile lines placed in farm fields.

The youngest bedrock in eastern Douglas County is of Pennsylvanian age. Up to 30 m (100 ft) of the Modesto Formation (shales, thin sandstones, and thin limestones) are present in the high bedrock areas. The Danville No. 7 Coal is thin but continuous over the entire mine area. Mostly shale, with some thin sandstone and limestone units, lie between the No. 7 and the Herrin No. 6 coals. The Herrin No. 6 Coal is approximately 2 m (6 ft) thick and is the coal being extracted at the Murdock and No. 5 mines. The total thickness of Pennsylvanian strata overlying the No. 6 Coal is quite variable and approaches zero outside the mine boundary; the No. 6 Coal has been eroded away in the bedrock valleys. Immediately below the Herrin No. 6 coal is an underclay whose thickness ranges from 1 to 2 m (3 to 6 ft).

The deeper geologic strata below the Alternative C site are presented in Figure 4.22. An additional 41 to 55 m (135 to 180 ft) of Pennsylvanian shale, sandstone, coal, and clay underlie the Herrin No. 6 Coal. These strata belong to the Carbondale and Spoon formations, and perhaps the Abbott Formation.

Below the Pennsylvanian strata lie 119 to 159 m (390 to 520 ft) of Borden siltstones and shales; 0 to 3 m (0 to 10 ft) of Chouteau Limestone; and 21 to 40 m (70 to 130 ft) of black, brown, and green, fine-grained shale of the New Albany Group. These units are of Mississippian age. The structural contours for the base of the New Albany Shale are heavily influenced by the Murdock

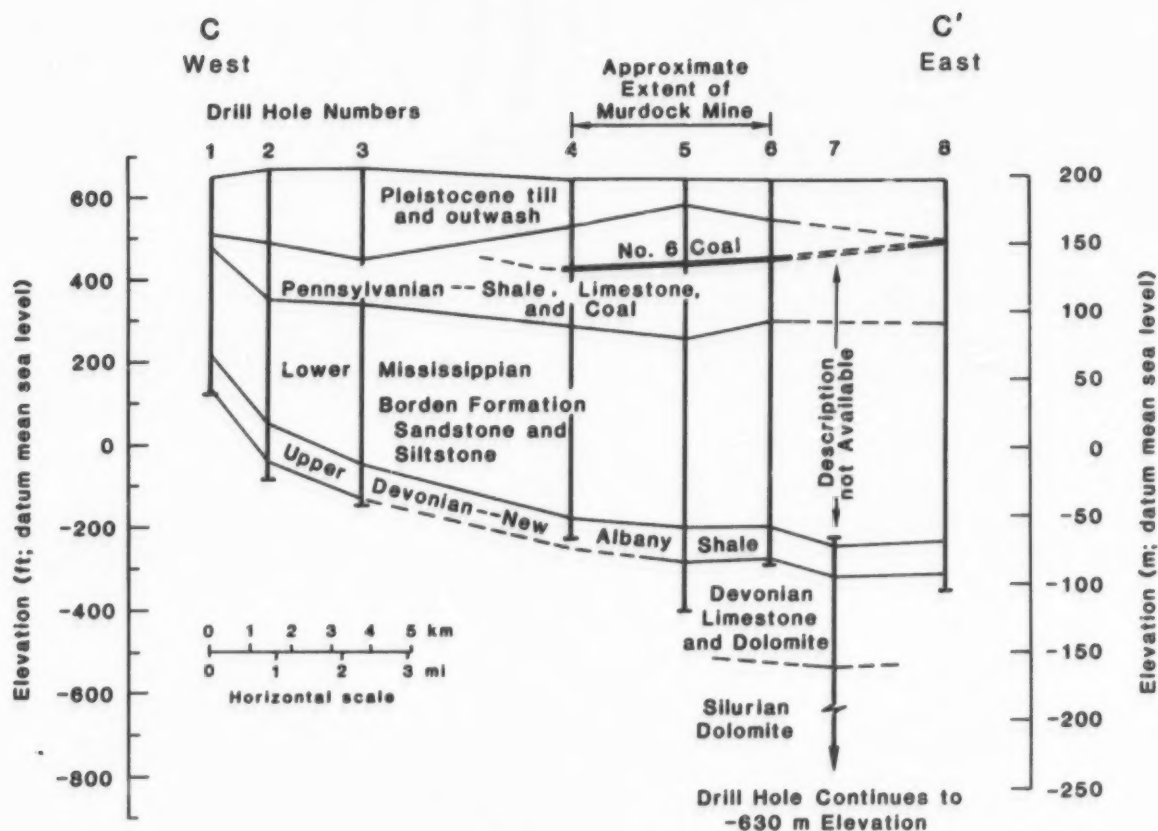


Figure 4.22. East-West Cross Section through the Underground Coal Mine Site (location of drill holes shown in Figure 4.5; sources of drill hole data listed in Table 4.14).

syncline; the strata dip toward the axis of the syncline and to the south in the direction of plunge (Cluff et al. 1981).

Below the Mississippian strata lie approximately 17 m (55 ft) of the Lingle Limestone (cherty and dolomitic limestones), 37 m (120 ft) of Grand Tower Dolomite (sandy), and 17 m (55 ft) of Dutch Creek Sandstone, all of Devonian age. Silurian dolomites and carbonates (Moccasin Springs Formation, St. Clair Limestone, and Sexton Creek Dolomite) are the next lower stratigraphic unit; the thickness of these two units is about 183 m (600 ft). Together, the Silurian and Devonian strata form the most productive bedrock aquifer in Douglas County (Selkregg and Kempton 1958; Kempton et al. 1982). Along the LaSalle anticlinal belt, Silurian and Devonian strata closely approach the land surface and are overlain directly by glacial drift (see Figure 4.19). Tuscola and Villa Grove obtain groundwater supplies from the Silurian and Devonian formations. Villa Grove has two wells that penetrate both Pennsylvanian and Mississippian shales and are finished at depths of

about 190 and 197 m (625 and 645 ft) into the Devonian Dutch Creek Sandstone (Selkregg and Kempton 1958). Several domestic wells also obtain small groundwater supplies from the upper part of the Silurian and Devonian strata near the LaSalle anticline. If this aquifer is drilled more than 1.6 km (1 mi) away from its subcrop or more than 119 m (390 ft) deep, mineralized and marginally potable water will likely be encountered (Selkregg and Kempton 1958; Kempton et al. 1982).

Below the Silurian-Devonian aquifer lies 73 m (240 ft) of the Ordovician Maquoketa Group, which consists of dark gray shales and dolomites. This group is a major aquitard in the deep basin hydrologic system. A deep drill hole in Section 30, T16N, R11E -- approximately 6 km (4 mi) east of Murdock -- penetrated to a depth of 823 m (2,700 ft) (elevation at bottom: 630 m below mean sea level). This well penetrated 209 m (685 ft) deeper than the base of the Maquoketa Shale Group, passing through the Galena, Platteville, and Ancell groups and into the Knox Megagroup of Lower Ordovician-Upper Cambrian age.

4.6.5 Farmland Site (Alternative D)

The farmland site is located in the northeastern corner of Livingston County. The Marseilles morainic system (a combination of the Norway and Ransom moraines) and the Minooka moraine enclose a broad topographic basin (Morris Basin) that occupies nearly all of Grundy County and the northeastern corner of Livingston County (Figure 4.23). The uppermost glacial till found in this area is the Yorkville Till Member (Wisconsinan Stage, Woodfordian Substage), which comprises the three moraines and much of the Morris Basin surface material (Willman and Frye 1970; Lineback 1979). The Yorkville Till, whose type section is located in the northern part of the Ransom moraine, is described as a greenish-gray to dark-gray clayey till (Willman et al. 1975). Willman and Frye (1970) report that Yorkville samples from this type section had an average matrix grain size distribution of 12% sand, 38% silt, and 50% clay, and an average clay mineral composition of 6% expandable clays, 78% illite, and 16% kaolinite plus chlorite.

The Yorkville Till Member was further investigated in Grundy and surrounding counties by the Illinois State Geological Survey in the late 1970s. The Yorkville was differentiated into an upper Dwight mineralogical zone and a lower Yorkville unit, based on slight differences in clay mineral composition and carbonate content (Killey 1980, 1982). Both Yorkville units are primarily till, with thin lenses and beds of clay and silt lacustrine deposits. The analytical results of samples (surface, hand-auger, and boring) collected at 99 locations are summarized in Table 4.16. The Dwight and lower Yorkville tills are indistinguishable in matrix grain size, although both show a considerable range in each size fraction. These tills consist of about

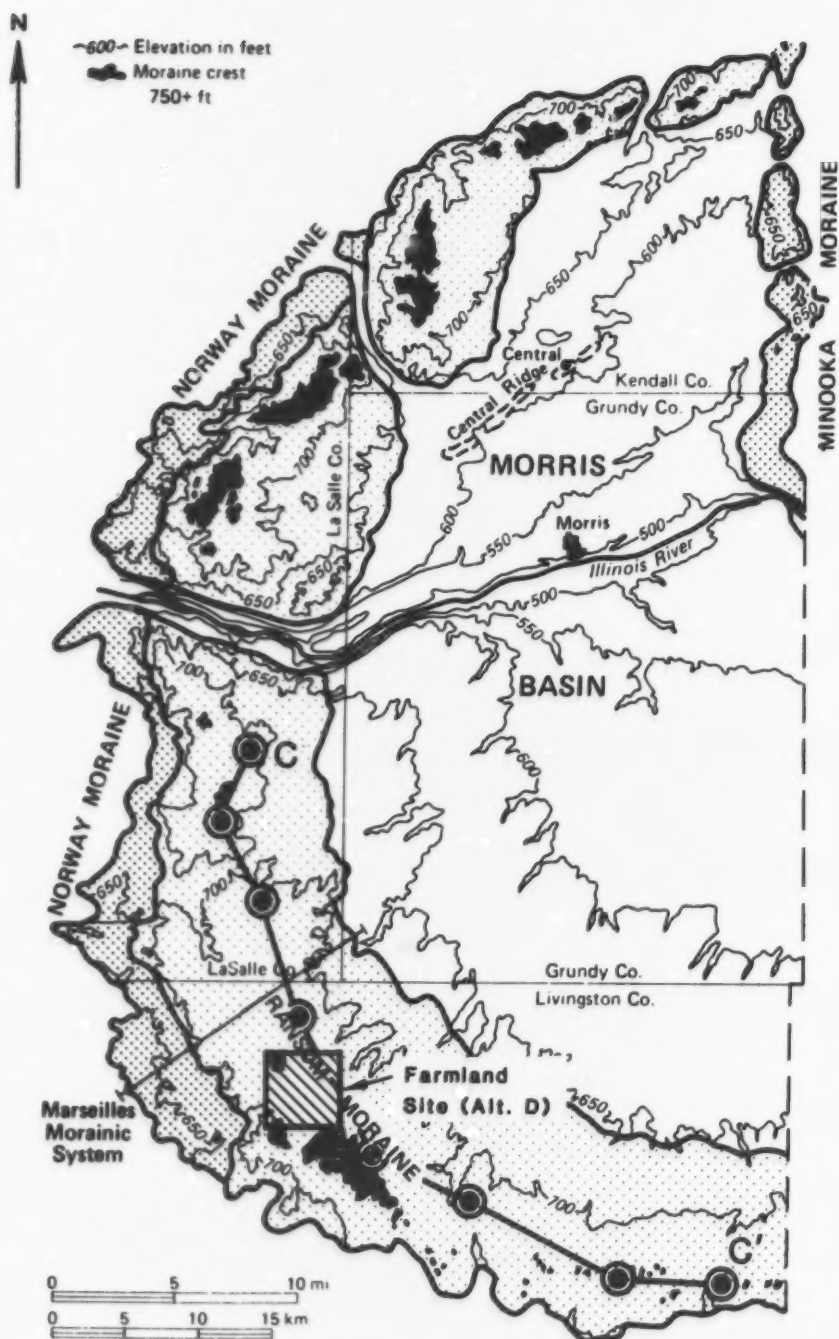


Figure 4.23. Glacial Moraines in the Vicinity of the Farmland Site.

Source: Modified from Killey (1982).

Table 4.16. Compositional Characteristics of Dwight and Lower Yorkville Till Samples

Characteristic	Dwight ^a				Lower Yorkville ^a			
	mean (%)	s.d. (%)	no.	range (%)	mean (%)	s.d. (%)	no.	range (%)
<u>Texture</u>								
Sand	10.33	5.75	48	4-31	13.02	6.65	132	2-36
Silt	43.15	8.14	48	24-57	43.49	6.99	132	19-68
Clay	46.52	12.18	48	12-71	43.55	10.62	132	17-70
<u>Clay Composition</u>								
Illite	76.35	2.16	49	72-81	81.47	1.65	141	77-85
Kaolinite and chlorite	20.84	2.26	49	15-25	16.99	1.66	141	13-22
Expandables	3.02	1.48	49	2-5	1.55	0.51	141	1-3
<u>Chittick Carbonate Content</u>								
Calcite	7.24	1.76	21	4-12	5.27	1.86	49	2-10
Dolomite	15.86	5.83	21	10-37	19.43	5.97	49	10-40

^a s.d. = standard deviation; no. = number of samples.

Source: Data from Killey (1982).

45% clay, 43% silt, and 12% sand. Dwight lake sediments are much higher in clay (averaging 70% clay, 29% silt, 1% sand), whereas lower Yorkville lake sediments (occurring at the contact between the two till units) have a high silt content, averaging 27% clay, 68% silt, and 5% sand (Killey 1982). Illite dominates both tills (76% and 81%, respectively), followed by kaolinite plus chlorite (21% and 17%, respectively) and expandable clays (3% and 2%, respectively). The calcite and dolomite contents of the two till units are also significantly different.

Figure 4.24 is a cross section through the Alternative D site and along the crest of the Ransom moraine. According to Killey (1980, 1982), the Norway moraine and most of the Ransom moraine are composed of lower Yorkville till. The Dwight zone, identified by mineralogical differences, is the upper part of the Yorkville Till Member and forms almost entirely the Minoaka moraine to the northeast. The two units of the Yorkville form the upper 20 to 30 m (65 to 100 ft) of glacial tills in the Ransom moraine. Only borehole LaS 40 (see Figure 4.24) penetrated completely through Pleistocene deposits and into bedrock. At this location, the Yorkville till and lake deposits and the surface loess form the upper 30 m (100 ft) of materials. Below the Yorkville

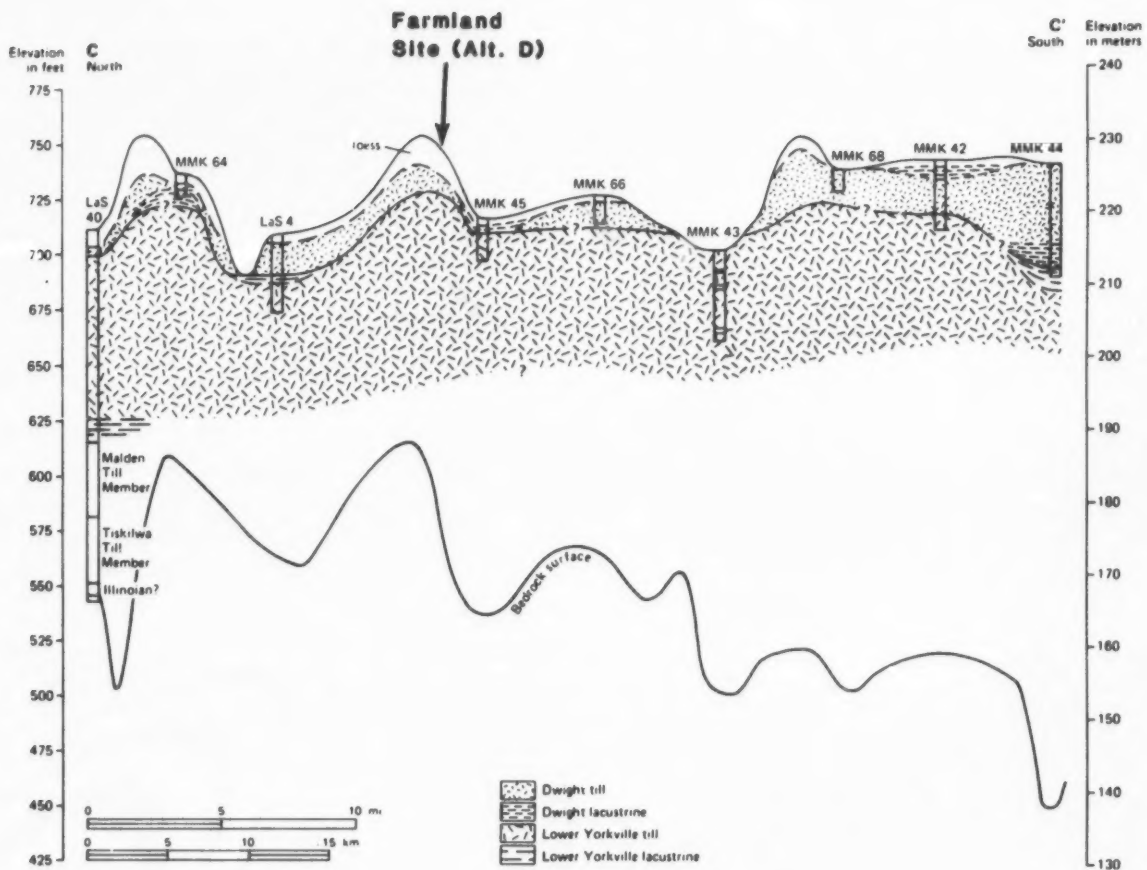


Figure 4.24. Cross Section C-C' of Glacial Deposits along the Crest of the Ransom Moraine South of the Illinois River (line of section shown in Figure 4.23).

Source: Modified from Killey (1982--Fig. 11b).

deposits lie about 10 m (33 ft) of the Malden Till Member and 10 m (33 ft) of the Tiskilwa Till Member (Killey 1982), which are lower members of the Wedron Formation. The Malden Till is a gray-tan to yellow-gray silty to sandy clay till, with an illite content intermediate between the overlying Yorkville and the underlying Tiskilwa Till Member. The Tiskilwa is a pink-tan to reddish tan-brown sandy till, which has less illite (about 65%) than most other Wedron till members. Both of these tills underlie much of the Marseilles moraine system (Killey 1982).

The Pleistocene tills and lake deposits overlie 75 to 99 m (245 to 325 ft) of shale, clay, limestone, sandstone, and coal of the Pennsylvanian System. The Pennsylvanian bedrock surface elevation in the Alternative D site area ranges from about 149 to 183 m (490 to 600 ft). A map and discussion of

the bedrock surface topography at the Alternative D site and the surrounding area are presented by Jacobson (1985). The base elevation of the Pennsylvanian strata ranges from about 75 to 119 m (245 to 390 ft).

Figure 4.25 is a cross section of Pennsylvanian strata in the Alternative D site area. Borehole 6 penetrated one of the thickest sequences of Pennsylvanian strata in Illinois, which is one reason why the area was chosen as the Alternative D site (see Appendix A, Section A.6). Shales, siltstones, and clays are the dominant Pennsylvanian lithologies; sandstones and limestones are present to a lesser extent. Seven coal seams of the Carbondale Formation are present in the site area. An extensive review of coal resources in northeastern Illinois (Jacobson 1985) shows that the coal seams in the site area have never been mined and that the potential for future mining is low.

The lowermost coal of the Carbondale Formation is the Colchester No. 2 Coal, which has been extensively mined (surface and underground) farther north in Grundy and LaSalle counties since the late 1800s. Figure 4.26 is a structure contour map of the No. 2 Coal in the Alternative D site area. The Pennsylvanian strata, including the No. 2 Coal, generally dip to the south and southwest. However, a local structural basin is present, and the Pennsylvanian strata are slightly thicker at the Alternative D site than in the surrounding area. Underlying the No. 2 Coal is an additional 15 to 24 m (50 to 80 ft) of Pennsylvanian strata.

Figure 4.27 is a cross-sectional diagram through Pennsylvanian and deeper strata. The Pennsylvanian Group lies unconformably over the Upper Ordovician Maquoketa Group (Willman et al. 1967); Silurian, Devonian, and Mississippian rocks were either never deposited or were eroded before Pennsylvanian time (see Appendix A, Section A.6). The Maquoketa Group is also absent as a result of erosion farther north in portions of Grundy and LaSalle counties. In the Alternative D site area, the Maquoketa Group is about 44 to 49 m (145 to 160 ft) thick and is a major aquitard in Illinois, forming the upper confining unit of the Cambrian-Ordovician Midwest Bedrock Aquigroup (Visocky et al. 1985). The Maquoketa Group consists of three formations: the upper Brainard Shale, the middle Fort Atkinson Limestone, and the lower Scales Shale (Templeton and Willman 1963; Buschbach 1964; Willman et al. 1975; Kolata and Graese 1983).

Below the Maquoketa Group lies the Cambrian-Ordovician Midwest Bedrock Aquigroup, most often referred to as the Cambrian-Ordovician aquifer in northeastern Illinois (Visocky et al. 1985). This unit is the first major aquifer to be encountered in the subsurface in this area. The surface elevation of this aquifer unit is about 30 to 61 m (100 to 200 ft) in the Alternative D site area. The upper part of the aquifer consists of the Galena Group (mainly limestones and dolomites), the Platteville Group (cherty

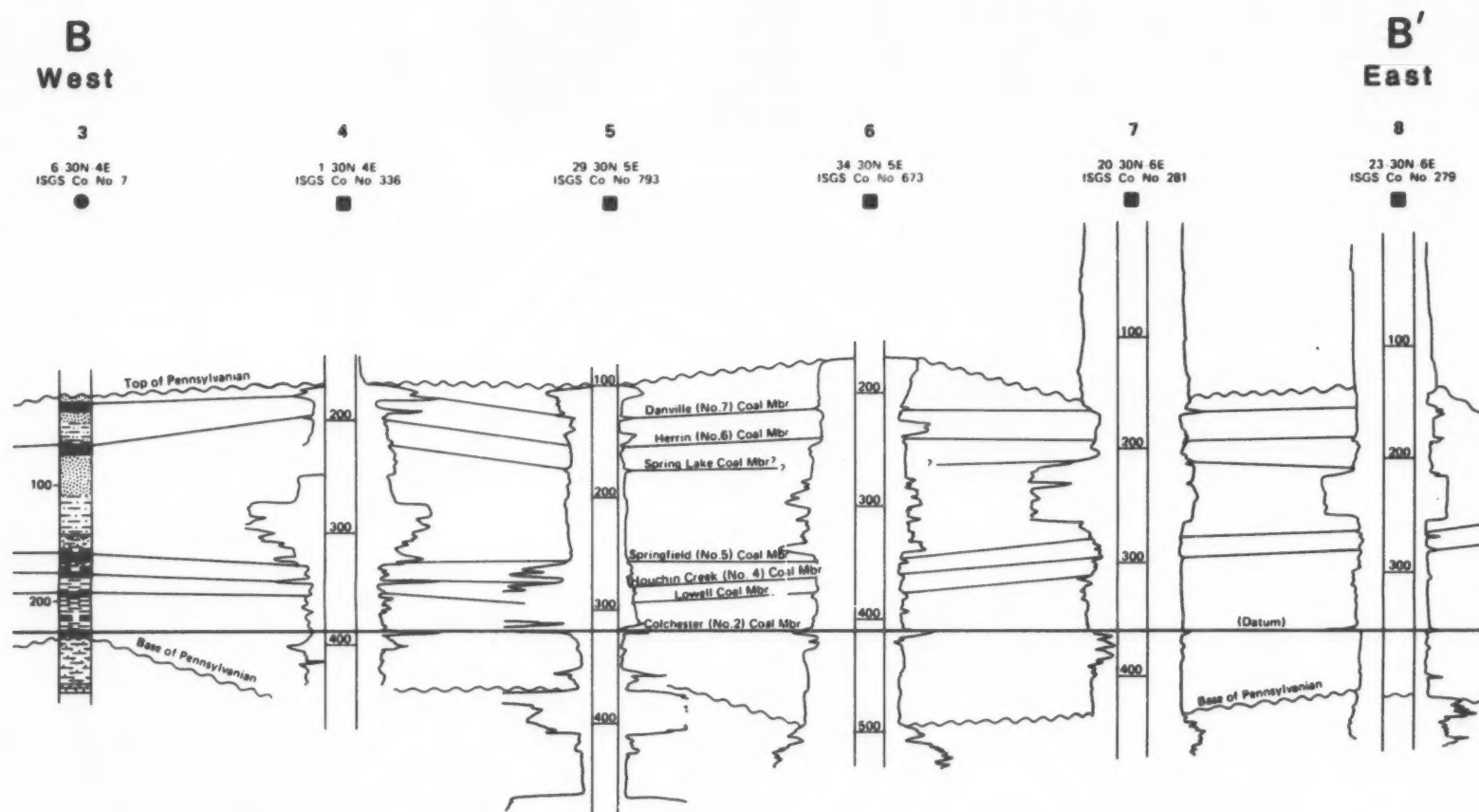


Figure 4.25. Geologic Cross Section B-B' of Pennsylvanian Strata in the Farmland Site Area (line of section shown in Figure 4.26).

Source: Modified from Jacobson (1985).

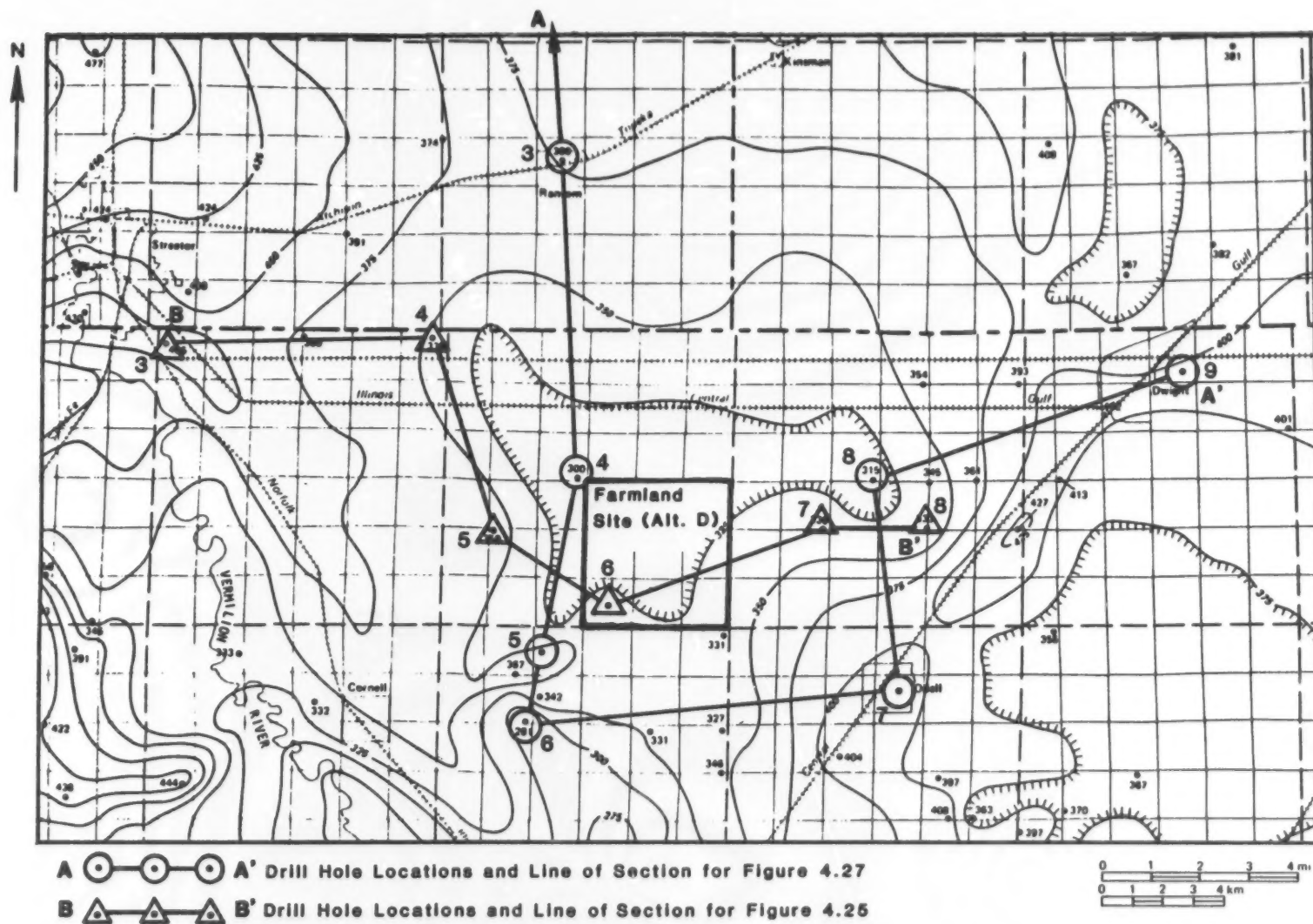


Figure 4.26. Structure Map of Colchester No. 2 Coal.
Source: Modified from Jacobson (1985).

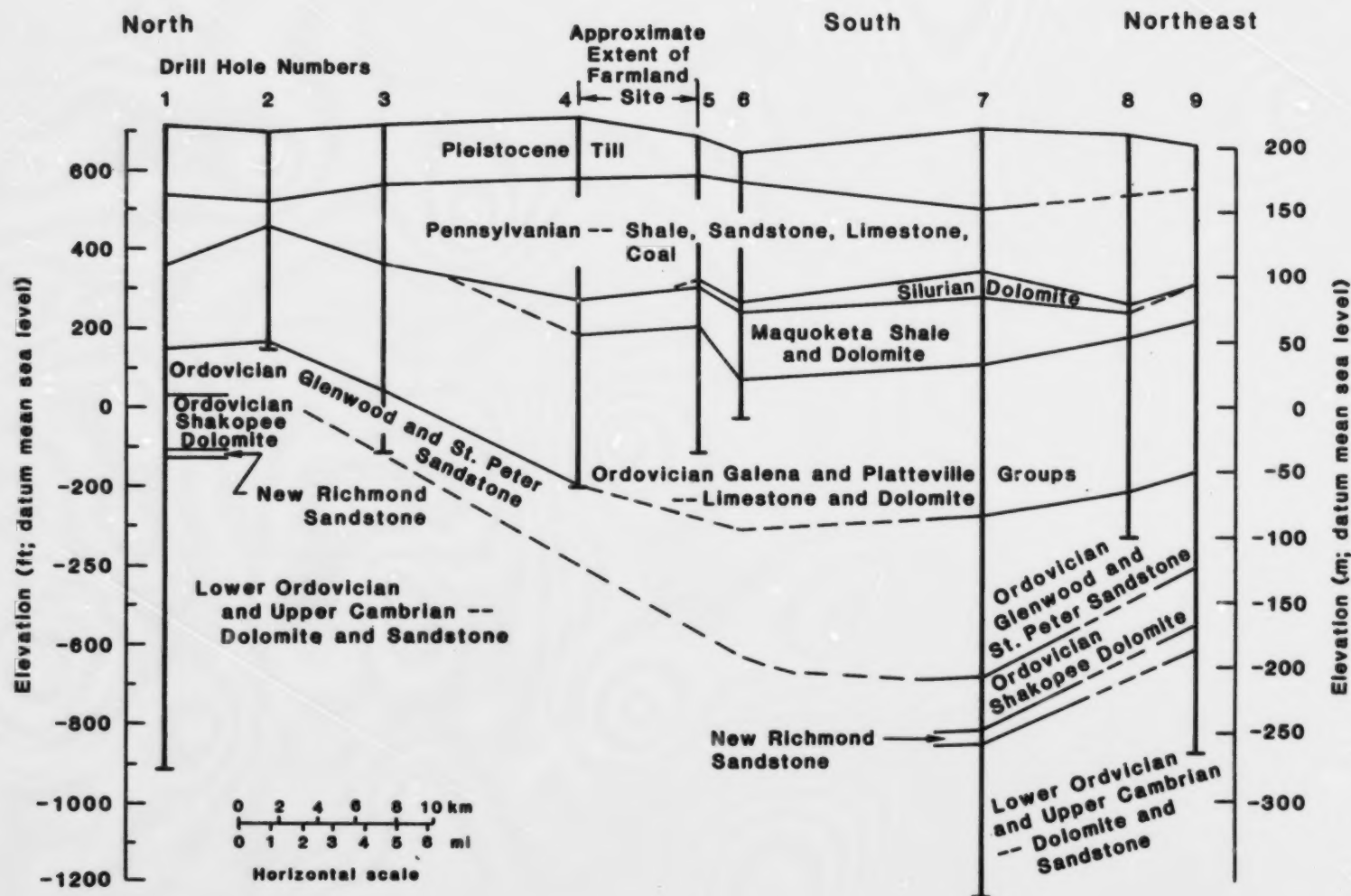


Figure 4.27. Geologic Cross Section A-A' of the Pennsylvanian and Deeper Strata in the Farmland Site Area (line of section shown in Figure 4.26; sources of drill hole data listed in Table 4.14).

dolomites and dolomitic limestones), and the Ancell Group (St. Peter Sandstone and dolomitic and shaly sandstones of the Glenwood Formation), in descending order. These three groups are of Champlainian age (Middle Ordovician). The Galena and Platteville groups are about 119 m (390 ft) thick, and the Ancell Group is about 59 m (195 ft) thick at the Alternative D site.

The middle section of the Cambrian-Ordovician aquifer consists of the Prairie du Chien Group (cherty dolomite with some interbedded sandstone), Jordan Sandstone, Eminence Formation (sandy dolomite with some chert and thin sandstone strata), Potasi Dolomite, and Franconia Formation (argillaceous sandstone and dolomite), in descending stratigraphic order. These units (the Knox Megagroup) form the center section of the Cambrian-Ordovician aquifer and are generally less permeable than the upper and lower parts of the Cambrian-Ordovician aquifer and have been grouped together as a confining unit within the aquifer (Visocky et al. 1985). However, some dolomites and sandstones within the Knox Megagroup contribute significant quantities of water to wells. For example, the New Richmond Sandstone is relatively thick, has considerable artesian head, and contributes significant quantities of water to wells in parts of LaSalle and Grundy counties (Visocky et al. 1985). The total thickness of the Knox Megagroup is about 244 to 290 m (800 to 950 ft) in the Alternative D site area.

At the base of the Cambrian-Ordovician aquifer are the Ironton and Galesville Sandstone formations, which are commonly referred to as the Ironton-Galesville aquifer in northern Illinois. These sandstones are the most uniform and productive water-bearing zones in the Cambrian and Ordovician systems in Illinois north of the Illinois River (Visocky et al. 1985). South of the Illinois River, the sandstones become finer, gradually changing to shale and then to dolomite in the deeper parts of the Illinois Basin. In the Alternative D site area, the combined Ironton and Galesville sandstones are about 61 m (200 ft) thick.

The Lombard and Proviso Members of the Eau Claire Formation form a confining unit between the Ironton-Galesville aquifer above and the Elmhurst-Mt. Simon aquifer below. These two stratigraphic units consist of dolomite, dolomitic sandstone, siltstone, and shale. Visocky et al. (1985) estimate that the thickness of the Lombard-Proviso members is approximately 149 m (490 ft) in the Alternative D site area.

The lowermost Cambrian sedimentary rocks are the Elmhurst and Mt. Simon sandstones. Although not penetrated by any drill holes in Livingston County, these sandstones (Elmhurst-Mt. Simon aquifer) are estimated to be about 760 m (2,500 ft) thick in northern Livingston County (Visocky et al. 1985). The base of these Cambrian sandstones rests unconformably on pre-Cambrian granite at an elevation about 1,370 m (4,500 ft) below mean sea level (Visocky et al. 1985).

4.7 WATER RESOURCES

4.7.1 Surface Water

4.7.1.1 West Chicago Site (Proposed Action)

Hydrology. The West Chicago site is on the western side of a divide that directs surface drainage either to Kress Creek or to the West Branch DuPage River (see Figure 4.1). The latter, which flows generally southward, lies east of the city of West Chicago. Kress Creek, which also flows southward, lies west and south of the Kerr-McGee facility. It crosses beneath the EJ&E Railroad about 430 m (1,400 ft) south of the Kerr-McGee facility, joining the West Branch DuPage River about 1.5 km (0.9 mi) south of West Chicago. The land in the vicinity of the site slopes gently to the southwest toward Kress Creek; hence, all surface drainage from the site is toward the creek. In addition to natural drainage, there is a drainage ditch that slopes in a southerly direction adjacent to the site, along the bed of the EJ&E Railroad tracks. This ditch also diverts runoff water to Kress Creek via a subsurface storm sewer crossing under Illinois Route 38 (FES--Sec. 4.8.1.1).

The U.S. Geological Survey, in cooperation with the state of Illinois, has maintained two gaging stations near West Chicago to measure water discharge and quality of the West Branch DuPage River. One gaging station is about 3 km (2 mi) northeast of West Chicago and the other is about 6 km (4 mi) southeast of the city. Flow data for the West Branch DuPage River recorded at these two gaging stations are summarized in Table 4.17. The U.S. Geological Survey (1974a, 1974b) delineated the 100-year-flood-prone areas for both the West Branch DuPage River and Kress Creek. The results indicate that the West Chicago site would not be inundated by a 100-year flood in these two nearby streams. Batra (1983) indicates that the probable maximum flow at the mouth of Kress Creek is about $88 \text{ m}^3/\text{s}$ ($3,100 \text{ ft}^3/\text{s}$). The corresponding water

Table 4.17. Flow Data for the West Branch DuPage River

Gaging Station Location	Years of Record	Drainage Area (km^2)	Discharge (m^3/s)		
			Average	Maximum	Minimum
Northeast of West Chicago	23	73.8	0.92	27.9	0.006
Southeast of West Chicago	16	234.1	2.86	61.2	0.22

Source: Data from Fitzgerald et al. (1985).

surface elevation is 223 m (730 ft) above mean sea level at river mile 1.3, a location just downstream of the EJ&E Railroad. Most of the Kerr-McGee facility is well above 223 m (730 ft); if flooding were to occur on the site, it would be limited to a very small area (less than 100 m²) in the southwestern corner (Batra 1983).

Water Quality. Concentrations of chemical species were measured from March 1974 to May 1979 in water discharged from the storm sewer outlet into Kress Creek. Measurements made in 1980 were restricted to a few major ion species; no radiological species were included. The results are presented in detail in Chapter 4 of the FES. These data show that concentrations of major ion species -- sulfate, nitrate, chloride, and sodium -- and total dissolved solids (TDS) appear to be decreasing over the measurement period. For example, TDS concentrations decreased from about 4,700 mg/L in 1974 to 290-1,400 mg/L in 1980. Fluoride concentrations also decreased from 21-25 mg/L in 1974, 1975, 1976, and May 1980 to 0.7-2.8 mg/L in 1977, 1979, and late 1980. Concentrations of copper ranged from 0.05 to 0.18 mg/L in 1976 to 1979, and those of nickel ranged from 0 to 10.2 mg/L over the same time period. Concentrations of natural uranium (2 ± 2 pCi/L), actinium-228 (<5 pCi/L), radium-226 (0.22 ± 0.05 pCi/L), and thorium-232 (1.1 ± 0.5 pCi/L) were measured in 1979.

As part of a regular monitoring program of Illinois water (Fitzgerald et al. 1984, 1985), concentrations of many chemical species in the West Branch DuPage River were measured for water years 1983 and 1984. The samples were collected at points several kilometers above and below the confluence of Kress Creek and the river. For most chemical species, average concentrations for 1983 were the same or lower below the confluence point than they were above. Only copper and iron were slightly higher below the confluence than above. For water year 1984, several species besides copper and iron (boron, chromium, fluoride, sodium) were higher below the confluence than above. Thus, in the 1983 data, there is no indication of nonradiological contamination of DuPage River water by surface runoff from the West Chicago site. There is also no evidence for or against nonradiological contamination from the West Chicago site in the 1984 data because the increased concentrations below the confluence could have been caused by contributions from other sources.

4.7.1.2 Active Surface Coal Mine (Alternative A)

Hydrology. The Alternative A site is situated next to a tributary of Swegle Creek, about 3.1 km (1.9 mi) upstream of the point where the tributary joins the creek (see Figure 4.3, which shows this tributary to be ephemeral). The tributary of Littlers Creek is about 1.9 km (1.2 mi) north of the site and joins Spoon River about 9 km (5.6 mi) northwest of the site. The

Spoon River Gaging Station at London Mills, which is about 6 km (3.7 mi) downstream from the Littlers Creek junction, records flow data for a drainage area of 2,776 km² (1,072 mi²) (Fitzgerald et al. 1985). The 42-year average flow is 20 m³/s (712 ft³/s); the maximum discharge recorded is 1,161 m³/s (41,000 ft³/s) and the minimum discharge is 0.2 m³/s (5.6 ft³/s). Topographic maps indicate that there are several ponds of water near the site, probably formed by surface runoff. The U.S. Geological Survey (1974c) study of flood-prone areas indicates that some parts of the active surface coal mine area might be affected by a 100-year flood on Swegle Creek.

Water Quality. The surface-water-quality gaging station nearest the Rapatee Mine is on the Spoon River at London Mills, about 9.6-11.3 km (6-7 mi) from the mine and 6.4 km (4 mi) downstream from Littlers Creek, which drains abandoned surface mine ponds near the mine. Water quality and river flow data at the gaging station for water year 1984 are given in Table 4.18. The data show that concentrations of most major ion species decreased somewhat during periods of high river flow in the spring and early summer. During this period, sulfate, calcium, sodium, and magnesium concentrations were, respectively, 54-78 mg/L, 63-83 mg/L, 9.1-13 mg/L, and 27-38 mg/L. At other times of the year, concentration ranges of these ions were, respectively, 67-130 mg/L, 66-90 mg/L, 16-42 mg/L, and 35-46 mg/L. Concentrations of nitrate plus nitrite (as nitrogen) were an exception in that concentrations were as low as <0.1 mg/L during periods of low flow, rising to 9.0 mg/L in periods of higher flow. Presumably this reversal can be attributed to fertilizer nitrates in the runoff, which increase in concentration during high flow periods. Most metal concentrations were low, <1 mg/L. Iron and aluminum were the exceptions, with concentrations reaching 15 mg/L and 11 mg/L.

4.7.1.3 Reclaimed Surface Coal Mine (Alternative B)

Hydrology. The Alternative B site is situated next to Clarks Branch and a tributary of the West Fork of Kickapoo Creek, about 3.5 km (2.2 mi) upstream of the point where the tributary joins the creek (see Figure 4.4). No flow records are available. Topographic maps indicate that the site is surrounded by several ponds of water.

The U.S. Geological Survey (1975a) study of flood-prone areas indicates that the site is not in the 100-year floodplain of the West Fork of Kickapoo Creek.

Water Quality. The surface-water-quality gaging station nearest the Elm Mine is on Kickapoo Creek at Bartonville, about 32 km (20 mi) downstream from the location where surface drainage from the area enters the West Fork of

Table 4.18. Water Quality and Flow Data for the Spoon River near the Rapatee Mine
for Water Year 1984, Alternative A

Parameter	Concentration (mg/L, except as noted)								
	Oct 18	Nov 29	Feb 8	Mar 21	Apr 16	May 22	Jun 25	Aug 1	Aug 29
Calcium	76	85	90	63	78	83	80	80	66
Magnesium	46	35	40	27	34	38	36	40	43
Sodium	42	20	25	9.3	9.1	13	16	28	38
Potassium	4.2	5.1	3.2	3.5	1.9	1.9	4.1	2.9	3.2
Alkalinity (CaCO ₃)	210	170	210	110	190	210	200	260	230
Sulfate	130	110	110	54	78	75	67	100	120
Nitrate plus nitrite (N)	<0.10	5.0	6.4	7.9	7.6	9.0	9.0	3.8	<0.10
Ammonia (N)	<0.1	0.26	0.35	0.19	<0.1	<0.1	<0.1	<0.1	<0.1
Phosphorus	-	-	0.16	0.74	<0.01	0.15	0.56	0.09	0.16
Aluminum	0.52	4.8	0.31	8.8	3.6	1.8	11	3.1	0.71
Barium	0.10	0.20	0.09	0.20	0.20	0.10	0.30	0.10	0.10
Boron	0.14	0.075	0.067	<0.05	0.057	0.059	0.088	0.18	0.11
Cadmium	<0.003	0.008	<0.003	0.006	<0.003	<0.003	0.009	<0.003	<0.003
Chromium	<0.005	0.008	0.006	0.022	<0.005	<0.005	0.012	0.015	<0.005
Cobalt	<0.005	0.009	<0.005	0.016	0.009	<0.005	0.013	<0.005	<0.005
Copper	<0.005	0.015	<0.005	0.018	0.012	0.006	0.015	0.11	<0.005
Iron	0.70	9.0	0.47	15	4.2	3.1	14	0.47	1.1
Lead	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	<0.1	<0.05	<0.05
Manganese	0.19	0.82	0.13	0.71	0.71	0.19	0.57	0.066	0.29
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	0.007	0.018	0.010	0.032	0.009	0.009	0.024	0.009	<0.005
Silver	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Strontium	0.27	0.22	0.23	0.13	0.16	0.18	0.20	0.24	0.23
Vanadium	<0.005	0.015	<0.005	0.023	0.016	0.005	0.022	<0.005	<0.005
Zinc	0.17	<0.10	<0.05	<0.1	<0.1	<0.1	0.11	<0.1	<0.05
pH (pH units)	7.5	8.6	7.2	7.7	7.3	7.6	7.5	7.8	8.0
Flow (m ³ /s)	2.3	30	9.3	150	51	200	21	5.0	1.6

Source: Fitzgerald et al. (1985); Gage station 569500. Values rounded to two significant figures.

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Kickapoo Creek. Water quality data for water year 1984 are given in Table 4.19. The data show that concentrations of some major ions decreased slightly during the spring and early summer. The concentration ranges of sodium, potassium, and sulfate during this period were, respectively, 14-26 mg/L, 1.7-3.1 mg/L, and 120-150 mg/L. During the remainder of the year, the respective concentration ranges were 32-47 mg/L, 2.9-4.7 mg/L, and 170-280 mg/L. Nitrate plus nitrite (as nitrogen) was an exception, with higher concentrations of 5.1-12 mg/L occurring in the spring and early summer than during the remainder of the year when the concentration range was 0.5-3.6 mg/L. Presumably this reversal can be attributed to fertilizer nitrates in runoff, which would be high during the periods of high flow that occur in the spring and early summer. Iron concentrations were also higher during the spring and early summer (0.84-3.9 mg/L) than during the remainder of the year (0.17-1.2 mg/L). Concentrations of most trace metals were <0.1 mg/L. Exceptions include aluminum, manganese, and strontium, which reached respective concentrations of 2.8 mg/L, 0.24 mg/L, and 0.35 mg/L.

4.7.1.4 Underground Coal Mine (Alternative C)

Hydrology. The Alternative C site is situated near the Jordan Slough, which is about 5.5 km (3.4 mi) to the north, and Brushy Fork, which is about 1 km (0.6 mi) to the south (see Figure 4.5). Jordan Slough joins the Embarras River near Villa Grove about 7.1 km (4.4 mi) from the site; Brushy Fork joins the Embarras River about 4 km south of the site. Branches of Jordan Slough and Brushy Fork flow rather evenly through the entire area of the site. Topographic maps indicate that there are several small ponds of water in portions of the site. The Embarras River Gaging Station near the city of Camargo, which is about 3.2 km (2.0 mi) southwest of Camargo and 6 km (3.7 mi) west of the site, records flow data for a drainage area of 482 km² (186 mi²) (Stahl et al. 1985). The 24-year average flow is 4.5 m³/s (160 ft³/s); the maximum discharge recorded is 177 m³/s (6,240 ft³/s); and no flow occurs for many days in most years (Stahl et al. 1985). The map of flood-prone areas (U.S. Geol. Surv. 1973) shows that the site is not in the 100-year floodplain of Jordan Slough or Brushy Fork.

Water Quality. The surface-water-quality gaging station nearest the Murdock and No. 5 mines is on the Embarras River at Camargo, a few kilometers upstream from any potential flow of surface runoff from the mines into Brushy Fork and then into the Embarras River. Water quality and river flow data for water year 1984 are given in Table 4.20. The data show that the water is of good quality, with major ions such as sulfate, sodium, and potassium at low concentrations during periods of high flow (43-50 mg/L, 4.0-9.1 mg/L, and 0.7-1.1 mg/L, respectively). During periods of low flow, concentrations were

Table 4.19. Water Quality Data for Kickapoo Creek at Bartonville, Illinois,
for Water Year 1984, Alternative B

Parameter	Concentration (mg/L, except as noted)								
	Nov 22	Jan 17	Mar 12	Apr 19	May 10	Jun 14	Jul 25	Aug 20	Sep 19
Calcium	100	130	110	95	100	99	96	100	120
Magnesium	48	55	48	43	49	44	48	54	66
Sodium	34	32	26	14	20	22	33	39	47
Potassium	4.7	2.9	2.4	1.7	1.9	3.1	3.3	3.5	4.0
Alkalinity (CaCO ₃)	250	320	270	250	-	250	260	270	270
Sulfate	200	200	150	120	140	120	170	230	280
Nitrate plus nitrite (N)	0.69	3.6	5.1	6.2	5.2	12	0.99	0.52	0.23
Ammonia (N)	<0.10	0.28	<0.10	<0.10	0.18	<0.10	<0.10	<0.10	<0.10
Phosphorus	-	-	0.080	0.090	0.060	0.16	0.070	0.080	0.33
Aluminum	0.20	0.11	0.41	0.66	0.46	2.8	0.87	0.43	0.23
Barium	0.094	0.091	0.081	0.083	0.090	0.10	0.10	0.10	0.10
Boron	0.15	0.14	0.088	0.083	0.11	0.12	0.15	0.16	0.20
Cadmium	<0.003	0.005	<0.003	<0.003	<0.003	0.004	0.004	<0.003	<0.003
Chromium	<0.005	0.006	<0.005	0.006	0.012	<0.005	0.007	<0.005	<0.005
Cobalt	<0.005	<0.005	<0.005	<0.005	<0.005	0.011	<0.005	<0.005	<0.005
Copper	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005
Iron	0.49	0.17	0.84	1.5	1.3	3.9	1.2	0.72	0.47
Lead	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Manganese	0.15	0.25	0.12	0.11	0.13	0.20	0.12	0.17	0.24
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	<0.005	0.008	<0.005	<0.005	<0.005	0.007	0.005	<0.005	<0.005
Silver	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Strontium	0.27	0.30	0.24	0.20	0.23	0.27	0.30	0.32	0.35
Vanadium	<0.005	0.006	<0.005	<0.005	<0.005	0.009	<0.005	<0.005	<0.005
Zinc	<0.10	<0.10	<0.050	<0.050	<0.10	<0.050	<0.050	<0.10	<0.050
pH (pH units)	8.2	7.3	7.4	7.8	7.7	7.7	8.1	7.8	7.7

Source: Fitzgerald et al. (1985); Gage station 563525. Values rounded to two significant figures.

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Table 4.20. Water Quality and Flow Data for the Embarras River at Camargo, Illinois,
for Water Year 1984, Alternative C

Parameter	Concentration (mg/L, except as noted)							
	Oct 6	Nov 30	Jan 9	Mar 14	Apr 30	Jun 7	Jul 17	Aug 28
Calcium	65	64	67	65	61	65	59	57
Magnesium	32	27	28	29	27	28	29	28
Sodium	77	6.1	9.	7.5	4.0	6.7	14	39
Potassium	5.8	1.2	0.7	0.7	1.0	1.1	1.4	4.0
Alkalinity (CaCO ₃)	200	140	180	160	150	170	170	190
Sulfate	110	43	50	48	50	46	53	65
Chloride	65	24	27	24	21	22	26	42
Nitrate plus nitrite (N)	0.19	10	9.4	10	10	12	3.9	0.29
Ammonia (N)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phosphorus	-	-	-	0.030	0.090	0.10	0.10	0.23
Aluminum	-	0.35	0.19	0.18	1.1	2.5	<0.05	0.71
Barium	0.096	0.050	0.044	0.041	0.053	0.072	0.057	0.081
Boron	0.28	<0.05	<0.05	<0.05	<0.05	0.055	0.074	0.15
Cadmium	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Chromium	0.013	<0.005	<0.005	<0.005	<0.005	0.014	<0.005	<0.005
Cobalt	0.014	<0.005	<0.005	<0.005	<0.005	0.010	<0.005	<0.005
Copper	0.006	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005
Iron	1.1	0.45	0.22	0.18	1.3	2.3	<0.05	0.79
Lead	0.092	<0.05	<0.05	<0.05	<0.05	0.11	<0.05	<0.05
Manganese	0.23	0.012	0.025	0.022	0.045	0.064	0.042	0.20
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	0.027	0.006	<0.005	<0.005	0.024	0.018	<0.005	<0.005
Silver	0.006	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003
Strontium	0.15	0.12	0.13	0.12	0.11	0.14	0.14	0.14
Vanadium	0.013	<0.005	<0.005	<0.005	<0.005	0.013	<0.005	<0.005
Zinc	0.11	<0.05	0.13	<0.05	<0.05	<0.05	<0.05	<0.10
pH (pH units)	7.5	7.1	7.3	7.7	8.0	7.7	6.4	8.0
Flow (m ³ /s)	0.13	20	2.2	2.8	9.1	4.0	0.37	0.11

Source: Fitzgerald et al. (1985); Gage station 343395. Values rounded to two significant figures.

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higher (53-110 mg/L, 1.4-77 mg/L, and 1.4-5.8 mg/L, respectively). Other ions such as nitrate plus nitrite (as nitrogen) were at higher concentrations (9.4-12 mg/L) during periods of high flow than during periods of low flow (0.19-3.9 mg/L). Presumably, this reversal can be attributed to fertilizer nitrates in runoff, which are appreciable during periods of high flow. Most trace metal concentrations were <0.1 mg/L. The exceptions were aluminum, iron, and strontium, which reached levels as high as 1.1 mg/L, 2.3 mg/L, and 0.15 mg/L, respectively. One sample (June 7, 1984) had a lead concentration of 0.11 mg/L.

4.7.1.5 Farmland Site (Alternative D)

Hydrology. The Alternative D site is located about 15 km (9.3 mi) southwest of the West Fork of the Mazon River and 15 km (9.3 mi) northeast of the Vermilion River (Figure 4.6). The Vermilion River gaging station at Pontiac records the flow data for a drainage area of 1,499 km² (579 mi²) (Fitzgerald et al. 1985). The 42-year average flow is 11.2 m³/s (394 ft³/s); the maximum discharge recorded is 371 m³/s (13,100 ft³/s), and no flow was recorded for several days in 1953, 1983, and 1984 (Fitzgerald et al. 1985). The Vermilion River Gaging Station near the city of Leonore records the flow data for a drainage area of 3,240 km² (1,251 mi²) (Fitzgerald et al. 1985). The 53-year average discharge is 23.4 m³/s (827 ft³/s), and the maximum and minimum discharges are 949 m³/s (33,500 ft³/s) and 0.14 m³/s (5.0 ft³/s), respectively. The U.S. Geological Survey (1975b, 1975c) study of flood-prone areas indicates that the farmland site is not in the 100-year floodplain of the Vermilion River.

Water Quality. The surface-water-quality gaging station nearest the farmland site is on the Mazon River, 6.4 km (4 mi) west of Coal City. The gaging station is about 24-32 km (15-20 mi) downstream from the site area. Water quality and river flow data for water year 1984 are given in Table 4.21. These data are similar to those for the other sites in that sulfate, sodium, and potassium concentrations were lower during periods of high flow (sulfate, 50-78 mg/L; sodium, 6.8-12 mg/L; and potassium, 1.3-1.8 mg/L) than during periods of low flow (sulfate, 180-300 mg/L; sodium, 61-81 mg/L; and potassium, 4.0-6.1 mg/L). Trace metal concentrations were <0.2 mg/L. Aluminum, iron, boron, and strontium were exceptions, with aluminum and iron concentrations as high as 0.90 mg/L and 1.2 mg/L, respectively. Boron concentrations were higher in low-flow periods (0.25-0.37 mg/L) than in high-flow periods (<0.05-0.11 mg/L). The same was true for strontium, with concentration ranges of 0.10-0.20 mg/L and 0.32-0.51 mg/L during periods of high flow and low flow, respectively. Presumably this pattern can be attributed to dilution during periods of high flow. Nitrate plus nitrite (as nitrogen) was an exception,

Table 4.21. Water Quality and Flow Data for the Mazon River near Coal City, Illinois,
for Water Year 1984, Alternative D

Parameter	Concentration (mg/L, except as noted)								
	Oct 13	Nov 18	Jan 25	Feb 17	Apr 2	May 4	Jul 3	Aug 7	Sep 12
Calcium	100	97	97	63	77	88	75	57	71
Magnesium	64	55	46	30	38	46	44	45	60
Sodium	64	61	21	6.8	9.0	12	25	81	61
Potassium	6.1	5.6	2.2	1.8	1.5	1.3	2.0	4.0	5.3
Alkalinity (CaCO ₃)	180	230	240	150	190	200	200	160	170
Sulfate	300	230	96	50	63	78	120	180	280
Nitrate plus nitrite (N)	0.3	3.3	9.9	8.3	12	13	7.7	<0.005	<0.005
Ammonia (N)	0.020	0.020	0.22	0.090	0.020	0.030	0.040	0.010	0.050
Phosphorus	-	-	-	0.16	0.050	0.020	0.060	-	0.080
Aluminum	0.72	0.19	0.11	0.90	0.69	0.26	0.57	0.30	0.28
Barium	0.071	0.051	0.047	0.050	0.038	0.037	0.050	0.055	0.074
Boron	0.33	0.25	0.11	<0.005	0.071	0.11	0.16	0.37	0.28
Cadmium	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.026
Iron	1.2	0.38	0.082	1.0	0.89	0.39	0.65	0.39	0.38
Lead	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Manganese	0.18	0.032	0.016	0.027	0.027	0.019	0.020	0.090	0.046
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	<0.005	0.005	<0.005	0.010	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003
Strontium	0.51	0.45	0.25	0.10	0.17	0.20	0.27	0.32	0.43
Vanadium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc	0.13	<0.05	<0.05	0.10	<0.05	<0.05	<0.05	<0.05	<0.10
pH (pH units)	7.4	7.8	7.5	7.1	7.6	7.6	7.7	7.8	7.9
Flow (m ³ /s)	0.31	0.79	2.5	42	17	11	1.2	0.21	0.11

Source: Fitzgerald et al. (1985); Gage station 542000. Values rounded to two significant figures.

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with higher concentrations during periods of high flow (8.3-13 mg/L) than during periods of low flow (<0.005-3.3 mg/L). Fertilizer nitrates dissolve during runoff, which is greater during periods of high flow.

4.7.2 Groundwater

4.7.2.1 West Chicago Site (Proposed Action)

Hydrology. Several distinct aquifers are recognized beneath the West Chicago area. From top to bottom, these aquifers are (1) glacial drift, (2) Silurian dolomite, (3) Galena-Platteville, (4) Glenwood-St. Peter, (5) Ironton-Galesville, and (6) Mt. Simon (Zeizel et al. 1962). Of these six aquifers, the glacial drift and Silurian dolomite aquifers are considered to be the most important shallow aquifers in the vicinity of the site (FES--Sec. 4.8.2.1).

The glacial drift aquifer is comprised of sand, gravel, silt, and clay deposited sporadically throughout the unconsolidated glacial drift, which overlies the bedrock to a depth of approximately 24 to 30 m (80 to 100 ft). Drillers' records obtained by Kerr-McGee (Law Eng. Test. Co. 1981a, 1981b) show that the water table in the glacial deposits at the West Chicago site is approximately 1.5 to 5.5 m (5 to 18 ft) below the surface. The water table gradient slopes in a southwesterly direction. The hydraulic gradient averages about 0.01, varying from about 0.004 in the east-central portion of the site to a maximum of 0.016 in the western portion of the site (FES--Sec. 4.8.2.1; Law Eng. Test. Co. 1981b).

The transmissivity ranges from 1.4×10^{-4} to 7.3×10^{-3} m²/s (1,000 to 51,000 gpd/ft) and averages 1.8×10^{-3} m²/s (12,325 gpd/ft). The hydraulic conductivity ranges from 7.9×10^{-5} to 2.0×10^{-3} m/s (167 to 4,250 gpd/ft²) and averages 6.6×10^{-4} m/s (1,408 gpd/ft²) (Law Eng. Test Co. 1981b). The groundwater velocity in the glacial drift aquifer was estimated to be about 1.76×10^{-5} m/s (5 ft/d) (Law Eng. Test Co. 1981b). The glacial drift aquifer is not used as a water supply or drinking water source in the West Chicago area and has very limited potential for human use (Kerr-McGee 1986--Vol. II).

The Silurian dolomite aquifer is considered a major groundwater source in the West Chicago area and was the first aquifer to be extensively exploited. It includes rocks of the Niagaran and Alexandrian series of the Silurian System and directly underlies the glacial drift. The thickness of the aquifer in the site area ranges from 15 to 46 m (50 to 150 ft) (Zeizel et al. 1962). Recharge of the Niagaran aquifer is from water percolating through the overlying glacial deposits. Recharge of the Alexandrian aquifer is from water infiltrating from the Niagaran Series. However, recharge rates are low because of the presence of less permeable shaly deposits within the Niagaran

Series. Groundwater moves easily through the open network of joints and fractures within the Silurian dolomite. Little or no filtration takes place in the aquifer, resulting in widespread migration of pollutants or contaminants once they reach the aquifer.

A recent report indicated that the natural flow in the glacial drift aquifer is primarily horizontal in the vicinity of the site (Kerr-McGee 1986--Vol. II). Only a very small percentage of the water entering the glacial drift aquifer from the surface percolates to the dolomite aquifer, and virtually no surface water from the site reaches the bedrock aquifer. Thus, only a small proportion of any solutes introduced into the glacial drift aquifer in the area reaches the dolomite aquifer. The solutes that do reach the dolomite aquifer are heavily diluted by large volumes of water flowing laterally (Kerr-McGee 1986--Vol. II).

Groundwater Withdrawal. Yields from wells in the West Chicago area were estimated to range from 31.5 to 94.6 L/s (500 to 1,500 gpm) (Zeizel et al. 1962). A study by the Illinois Department of Energy and Natural Resources indicates that there are many wells for public use in the shallow (less than 183 m [600 ft]) bedrock aquifer (Shafer 1985). The average pumpage from these wells is about 32.9 to 438 L/s (0.751 to 10 mgd).

A study performed by Argonne National Laboratory (1977) indicated that the piezometric gradient and flow direction in the dolomite aquifer were greatly influenced by pumpage at the city of West Chicago. The study also showed that in the area just north of the site boundary, the bedrock aquifer had a cone of depression with a potentiometric surface elevation of about 15 m (50 ft) below the ground surface. This cone was caused for the most part by pumpage of the dolomite aquifer by residents in the site area.

In late 1980, Kerr-McGee drilled six deep wells (KM-1, KM-2, KM-4, KM-5, KM-6, and KM-7) through the glacial materials at the site. These wells were completed into the top 1.5 m (5 ft) of the bedrock aquifer (Law Eng. Test. Co. 1981a). The results of preliminary water-level measurements in piezometers sealed in this aquifer indicated that the piezometric surface was approximately 5 to 13 m (16 to 44 ft) below the surface. The hydraulic gradient ranges from about 0.0005 to 0.0025 (FES--Sec. 4.8.2.1).

Water Quality. A large amount of data is available on concentrations of radiological and chemical species in groundwater underneath the Disposal Site for the Proposed Action and underneath the Kerr-McGee Factory Site. These data apply to three groundwater levels: (1) under the Disposal Site, shallow (from 3 to 8 m [10 to 25 ft] below the ground surface -- the B wells); (2) under the Disposal Site, deeper (from 25 to 30 m [81 to 100 ft] below the ground surface -- the KM wells), and (3) under the Factory Site (from 7.3 to

11 m [24 to 36 ft] below the ground surface -- the F wells) (Smith 1986). The locations of the B and KM wells on the Disposal Site and the F wells on the Factory Site are shown in Figure 4.28. The data available from 1981 on are presented in Appendix C. Earlier data (and some 1981 data) are given in Chapter 4 of the FES and in the Stabilization Plan (Kerr-McGee 1980--Chap. 3). The regulatory limit concentrations specified by the state of Illinois and the U.S. Environmental Protection Agency (EPA) are given in Tables 2.8 and 2.9.

Comparing the water-quality data in Appendix C, the FES, and the Stabilization Plan with the regulatory limits shows that, in the shallow groundwater under the Disposal Site (B wells), silver, boron, copper, iron, manganese, lead, zinc, fluoride, and sulfate concentrations and TDS values exceeded the Illinois general use water limits at one or more wells at some time during the 1980s. In particular, silver, copper, and fluoride concentrations exceeded the general use regulatory limits by factors of 10 or more at some time in one or more of the B wells. At some of the wells, concentrations of regulated parameters (e.g., fluoride, copper, sulfate, and TDS) exceeded the general use limits for most of the sampling dates. Concentrations of most species listed in Table 2.8 exceeded the EPA regulatory limits at one or more of the shallow B wells for one or more sampling times. However, the concentrations of barium and mercury were lower than the regulatory limits at all sampling sites at all times.

Except for one sample (Well B-3 in the third quarter of 1982), concentrations of radium-226 were below the Illinois general use water limits. All measured values of radium-226 and radium-228 were below the EPA regulatory limits.

The deeper groundwater under the Disposal Site is somewhat less contaminated than the shallower groundwater. In particular, concentrations of silver, copper, iron, lead, sulfate, and TDS exceeded the Illinois general use regulatory limits at one or more sampling times and points (KM wells). However, silver was the only species with a concentration 10 or more times above the general use regulatory limit. Concentrations of such species as fluoride and copper were less in the deeper water than in the shallower water under the site. However, concentrations of many of the regulated species listed in Table 2.9 in the deeper water exceeded the EPA limits and the Illinois public water supply limits. Concentrations of radium-226 in the deeper waters (KM wells) exceeded both the Illinois and EPA limits and were higher than in the shallower water.

Concentrations of many chemical and radiological species in groundwater under the Factory Site (F wells) were higher than those under the Disposal Site. Examples include nitrate concentrations in Well F-1 (up to 520 mg/L),

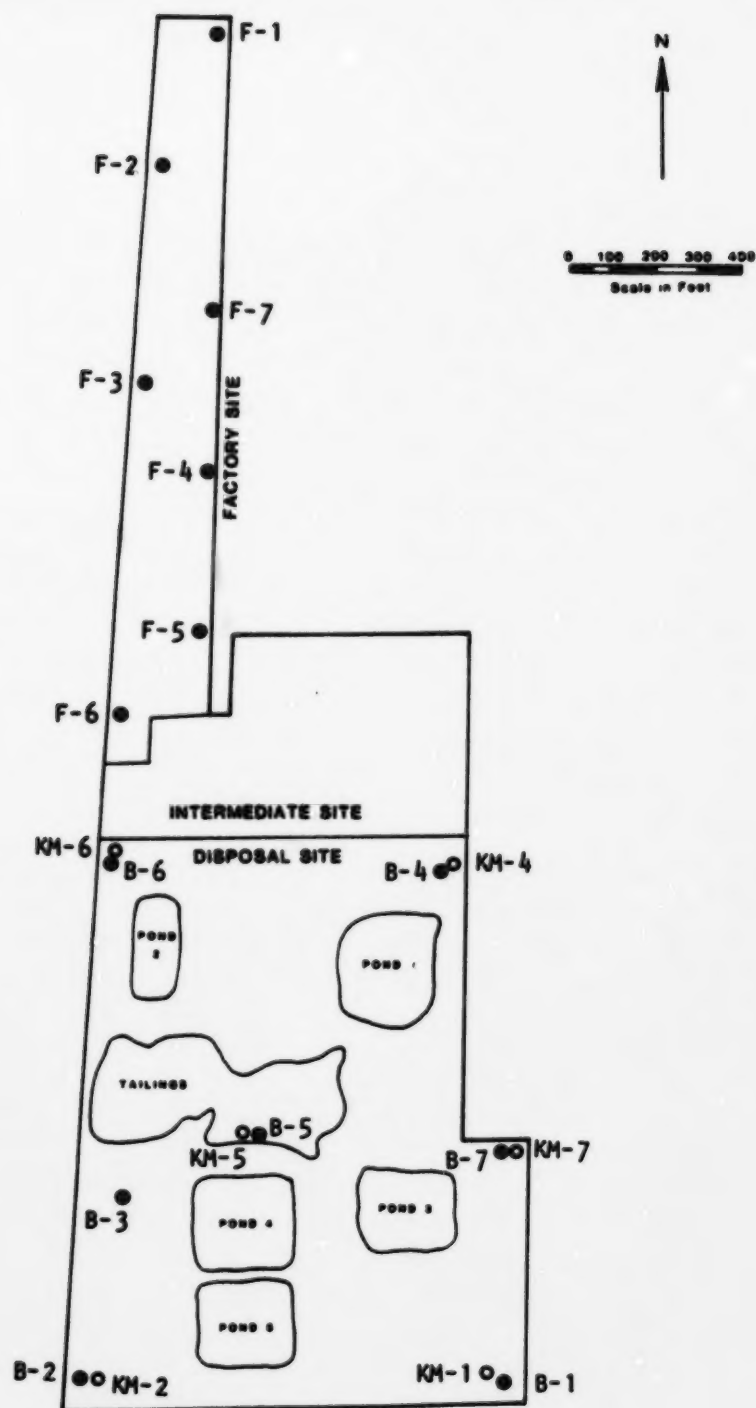


Figure 4.28. Locations of B, F, and KM Wells on the Kerr-McGee Factory Site.

Source: Modified from Kerr-McGee (1986--Vol. II, Figs. 2-1 and 2-49).

uranium concentrations in Well F-2 (up to 6.7 mg/L), zinc concentrations in Well F-2 (up to 6.5 mg/L), and sulfate concentrations in Well F-7 (4.5 g/L in 1985). However, the nitrate concentrations in Well F-1 decreased rapidly from a high of 520 mg/L measured in the second quarter of 1982 to values of 23-210 mg/L measured in 1984 (see Appendix C).

Concentrations in the F-well waters of most regulated chemical species listed in Table 2.9 exceeded the Illinois general use water limits. The exceptions were arsenic, barium, chromium (trivalent), nickel, mercury, and selenium, for which concentrations were below the general use limits at all sampling times. Except for barium, concentrations of all regulated species exceeded the EPA limits.

The time dependence of concentrations in the groundwater for various species was examined to see if leaching from the source had decreased in recent years compared with earlier years. For this purpose, concentrations of a species were averaged separately over the B, KM, and F wells for each sampling time, and the averages were plotted as a function of sampling time. Sulfate and fluoride were chosen because large amounts of these species had been discarded as waste (see Table 2.1), which should yield concentrations much higher than background. The results are shown in Figures 4.29 (sulfate) and 4.30 (fluoride). The B-series curves are averages over Wells B-1 to B-5 only because data are not available for Wells B-6 and B-7 before 1981.

The sulfate concentrations (see Figure 4.29) are highest in the F series, lowest in the KM series, and in between in the B series. Much less fluctuation occurred in the measured values for the KM series, probably because the KM series sampled a deeper aquifer that is not so susceptible to short-term variations in source material leaching, which is related to fluctuations in precipitation. The three curves show a decrease in concentration with time. This result is to be expected because sulfate is a mobile species that should be leached from the wastes fairly rapidly.

The curves in Figure 4.29 provide a crude estimate of the leach rate for mobile species like sulfate. If one assumes that the sulfate concentration decreases exponentially with time, one obtains values of 18, 15, and about 13 years, respectively, for the leach times* for the B, F, and KM wells. Of course, these estimates are crude because the data points fluctuate and only a few years of data are available.

*The time it takes the concentration to decrease to $1/e$ of its original value.

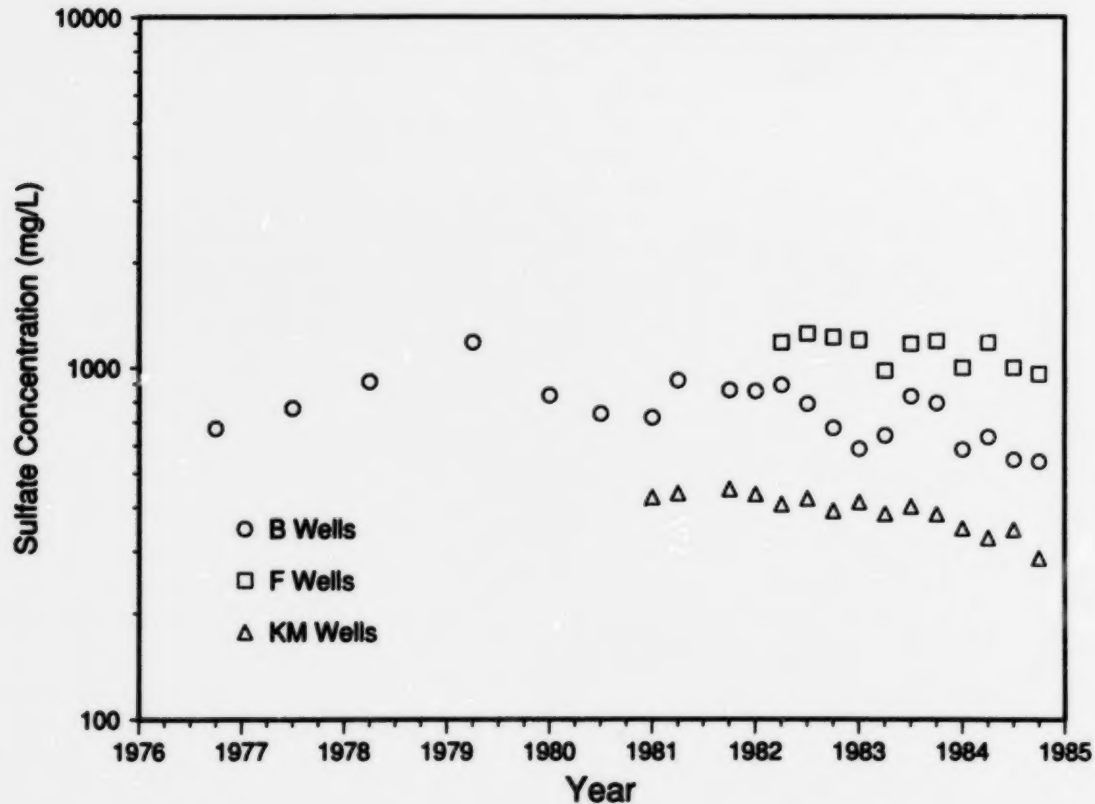


Figure 4.29. Sulfate Concentrations (mg/L) in B, F, and KM Wells as a Function of Sampling Time.

No such decrease with time occurs for the fluoride data (Figure 4.30). Except for the first two points, there is no general decrease with time for the B-series concentrations. The KM-series data cannot be used because most points are upper limits; the concentrations are much lower than those of the B- or F-series concentrations, with most values less than 1 mg/L. The F-series trend closely parallels part of the B-series trend and even suggests an increase in concentration with time.* However, data are not available over a long enough period to check whether this is indeed the case. The much

*Such an increase in concentration with time is to be expected for less mobile elements. Whether or not fluoride is less mobile than sulfate under the conditions at the site is not known. However, the low solubility of calcium fluoride and the presence of appreciable concentrations of calcium in the well water suggest that reduced mobility is possible.

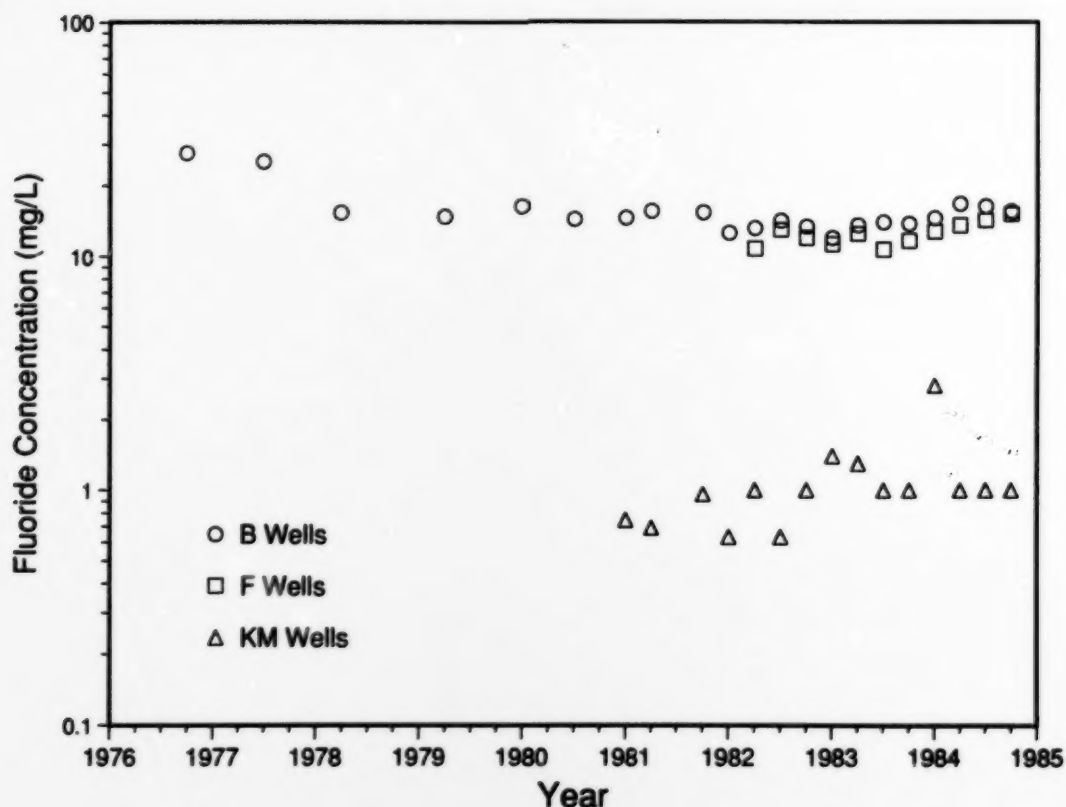


Figure 4.30. Fluoride Concentrations (mg/L) in B, F, and KM Wells as a Function of Sampling Time.

lower KM-series concentrations strongly suggest that most of the B- and F-series concentrations are the result of contaminants leaching from the source; that is, they do not represent background levels. However, the KM wells sample a different aquifer than the F and B wells.

The samples of water from the B, F, and KM wells taken in 1984 were analyzed for RCRA priority and nonpriority pollutant compounds. Except for acetone and methylene chloride, all results were below the detection limits, which are from 0.1 to 5 $\mu\text{g/L}$ for most species. The high positive values for acetone and methylene chloride should be disregarded because these chemicals were used in the analysis to rinse the bottles containing the water samples (Watson 1984b).

Separate samples of the B, F, and KM well waters were analyzed in 1983 and 1984 for total organic halides (Watson 1984a). According to the results presented in Table 4.22, two-thirds of the wells had higher concentrations in

Table 4.22. Concentrations of Total Organic Halides
in Monitoring Wells on the West Chicago Site

Well Number	Concentration ($\mu\text{g/L}$ chloride)	
	1983 4th Qtr	1984 1st Qtr
B-1	<5	33
B-2	6	5
B-3	<5	30
B-4	13	42
B-5	15	53
B-6	16	<5
B-7	6	21
F-1	6	10
F-2	19	96
F-3	27	15
F-4	20	7
F-5	<5	43
F-6	5	37
KM-1	11	71
KM-2	74	236
KM-4	25	151
KM-5	87	61
KM-6	32	48
KM-7	25	17
M1111-Q water blank	16	8
M1111-Q plus 50 $\mu\text{g/L}$ organic halide	19	-

Source: Watson (1984a).

the fourth quarter of 1983 than in the first quarter of 1984. Also, concentrations were higher in general for both periods in the deeper KM well water than in the shallower B and F well waters.

Concentrations of major ions were also measured in water samples taken in 1964, 1977, and 1979 from 34 wells drilled into the Silurian dolomite aquifer in the vicinity of the West Chicago site (FES--Tables 4.20-4.21 and Figs. 4.28-4.43). The measured sulfate concentrations and TDS values were in excess of the state water supply limits at one or more of the test well sites from 1964 through 1979. As noted in Chapter 4 of the FES, the data show that,

with regard to the major ions (chloride and sulfate), hardness, and TDS, water quality was improving over the years 1964-1977. Inclusion of the 1979 data shows that the zones of high pollutant concentrations have continued to decrease in size and that concentrations at outlying wells have increased. According to the FES (Chap. 4), these data suggest that these mobile contaminants are migrating away from the source and that leaching of mobile pollutants from the source materials has stopped or has been greatly reduced. However, the data in Appendix C and in Figures 4.29 and 4.30 show that large amounts of pollutants are still being leached out at the Disposal Site and Factory Site.

Concentrations of several trace metals, fluoride, phenols, and cyanide were measured in 1979 in water from the 34 wells in the Silurian dolomite aquifer (FES--Table 4.21). Positive results were obtained for most wells for boron, fluoride, lead, and zinc; positive results were obtained for some wells for barium, copper, and nickel. Silver, arsenic, cadmium, cyanide, mercury, and selenium were not detected; in addition, except for one well, chromium and phenols were not detected.

Of those species that gave positive results for one or more wells, phenols, zinc, lead, and copper concentrations were in excess of the state regulatory general use limits at one well (two wells for zinc). Concentrations at all the other wells were below the public water supply limits. The detection levels (Ill. Environ. Prot. Agency 1979) of the chemical parameters that were not detected, including chromium and phenols, were less than the Illinois public water supply limits (Table 2.9) except for silver and cadmium. Concentrations of these parameters were below the public water supply limit in all the wells for which the value zero is given in Table 4.21 of the FES. Concentrations of cadmium were less than or equal to the public water supply limit. No comparison is possible for silver because the detection limit is greater than the Illinois public water supply and general use limits (Table 2.9).

Concentrations of some radioactive species were measured in May 1979 in water samples taken from most of the same 34 wells. The radium-226 measurements were repeated in November 1979. Natural uranium (<1 to 4 ± 3 pCi/L), actinium-228 (<5 pCi/L), radium-226 (0.19 ± 0.03 to 19 ± 1 pCi/L), and thorium-232 (<0.2 pCi/L) were measured in the May 1979 samples. The November 1979 radium-226 results (0.29 ± 0.05 to 0.72 ± 0.10 pCi/L) were lower than the May results for almost all of the sampled wells. Six of the wells sampled in May 1979 had radium-226 concentrations in excess of the EPA limit of 5 pCi/L (40 CFR Part 141).

4.7.2.2 Active Surface Coal Mine (Alternative A)

Hydrology. Groundwater in the Alternative A site area occurs in unconsolidated glacial deposits of Pleistocene age, limestone and dolomite of Mississippian through Silurian age, and sandstone of Cambrian-Ordovician age (Zuehls et al. 1981; Shafer 1985). Figure 4.15 is a geologic cross section of the area. All aquifers of Silurian age or younger are usually referred to as shallow aquifers whereas aquifers of Cambrian-Ordovician age are referred to as deep aquifers. Generally, the shallow aquifers are used for domestic supplies and the deep aquifers are developed for high-capacity wells.

Yields from wells in sand and gravel aquifers vary considerably throughout the site area, with some locations providing yields of 1.3 L/s (20 gpm) or more. The chances of obtaining a well yielding 1.3 L/s (20 gpm) or more from shallow bedrock aquifers are small whereas deep sandstone wells commonly yield between 6.3 and 32 L/s (100 and 500 gpm) (Zuehls et al. 1981; Shafer 1985). However, a deeper aquifer is often an unsatisfactory source of water for most users because of high concentrations of dissolved solids.

Groundwater Withdrawal. Groundwater pumping in Fulton County, in which the Alternative A site is located, was estimated to be 153 L/s (3.5 mgd) in 1984 (Kirk et al. 1985). This pumpage was relatively small compared with total groundwater pumping in the northern half of Illinois. Pumpage in northern Illinois from the Cambrian-Ordovician aquifer alone averaged 12,222 L/s (279 mgd) from 1971 to 1980 (Visocky et al. 1985). The total withdrawal in Fulton County in 1984 consisted of 44 L/s (1.0 mgd) for public supply, 4.4 L/s (0.1 mgd) for self-supplied industries, and 105 L/s (2.4 mgd) for rural domestic and livestock uses. Most of the public and industrial groundwater supplies were pumped from glacial drift and deep bedrock aquifers (Kirk et al. 1985).

Water Quality. Total dissolved solids concentrations in the groundwater of the Alternative A site area tend to increase with depth. The TDS concentrations in wells in unconsolidated deposits are likely to be less than 500 mg/L whereas those in groundwater from shallow bedrock aquifers are likely to be 1,500 mg/L or more (Zuehls et al. 1981). The TDS concentrations in groundwater from the Cambrian-Ordovician aquifer increase southward, in addition to increasing with depth. The TDS concentration is about 1,800 mg/L in the Galena-Platteville dolomites and the Glenwood-St. Peter sandstones of Ordovician age and about 5,000 mg/L in the Ironton-Galesville aquifer of Cambrian age (Visocky et al. 1985).

4.7.2.3 Reclaimed Surface Coal Mine (Alternative B)

Hydrology. Because of their close proximity, the Alternative B site in western Peoria County and the Alternative A site in northeast Fulton County have similar geohydrologic conditions.

Yields in wells tapping sand and gravel aquifers vary widely in the Alternative B site area, with some locations providing yields of 1.3 L/s (20 gpm) or more. The chances of obtaining a well yielding 0.6 L/s (10 gpm) or more from shallow bedrock aquifers are small whereas deep sandstone wells commonly yield between 6.3 and 32 L/s (100 and 500 gpm) (Zuehl et al. 1981; Shafer 1985). However, high concentrations of TDS often make this deeper aquifer an unsatisfactory source of water for most uses (Zuehl et al. 1981).

Groundwater Withdrawal. Groundwater pumping in Peoria County, in which the Alternative B site is located, was estimated to be 1,600 L/s (35.4 mgd) in 1984. Most pumping took place near Peoria, about 19 km (12 mi) east of the Alternative B site. Total groundwater withdrawal within T9N, R5E (which contains the Alternative B site), was estimated to be only 8.8 L/s (0.2 mgd) (Kirk et al. 1985).

Water Quality. As is true for the Alternative A site, TDS concentrations in groundwater near the Alternative B site tend to increase with depth. Concentrations are likely to be about 500 mg/L or less in the unconsolidated deposits and about 1,500 mg/L or more in the shallow bedrock (Zuehl et al. 1981). The TDS concentrations in groundwater from the Cambrian-Ordovician aquifer increase southward as well as with depth. The concentrations are about 1,800 mg/L in the Galena-Platteville aquifer, 1,700 mg/L in the Glenwood-St. Peter sandstones, and 5,000 to 10,000 mg/L in the Ironton-Galesville aquifer (Visocky et al. 1985).

4.7.2.4 Underground Coal Mine (Alternative C)

Hydrology. Groundwater in the Alternative C site area in Douglas County occurs in shallow sand and gravel aquifers and in Silurian and Devonian dolomites. The glacial drift is about 15-61 m (50-200 ft) thick in the vicinity of the site. Although the groundwater potential of the glacial drift has not been explored extensively, the area is not expected to contain extensive sand and gravel aquifers (Kempton et al. 1982). Wells within 8 km (5 mi) of the Alternative C site yield 0.4 to 7.3 L/s (6 to 115 gpm) (see Table 4.23). Tuscola and Villa Grove, located about 16 km (10 mi) west and 13 km (8 mi) northwest of the site, respectively, obtain their water supplies from the Silurian and Devonian formations (Selkregg and Kempton 1958). A number of

Table 4.23. Sand and Gravel Aquifer Test Data for Wells near the Underground Coal Mine Site

Well Location			Depth (ft)	Non- pumping Level (ft)	Pumping Rate (gpm)
Township, Range	Section	Owner			
15N, 10E	35	University of Illinois	63	28.4	6
	36	Douglas County Conservation Area	36	9.6	10
16N, 9E	34	Village of Camargo	81	4.2	25
	34	Village of Camargo	72	13.2	60
16N, 11E	31	City of Newman	58	10.2	115
16N, 14W	31	City of Newman	127	21.1	27
	31	City of Newman	143	2	117
	32	City of Newman	30	4.5	70

Well Location		Observed Specific Capacity (gpm/ft)	Transmis- sivity (gpd/ft)	Hydraulic Conductivity (gpd/ft ²)	
Township, Range	Section				
15N, 10E	35	0.4	990	-	
	36	5.5	4,330	540	
16N, 9E	34	1.4	2,400	-	
	34	4.4	13,400	1,120	
16N, 11E	31	21.4	48,000	3,000	
16N, 14W	31	0.4	500	-	
	31	1.3	2,300	135	
	32	7.4	21,300	1,060	

Source: Data from Kempton et al. (1982).

domestic wells also obtain small groundwater supplies from the upper part of these two formations near the LaSalle anticline (see Section 4.6.4).

Groundwater Withdrawal. Groundwater pumping in Douglas County, where the Alternative C site is located, was estimated to be 74 L/s (1.7 mgd) in 1984, including 44 L/s (1.0 mgd) for public supplies and 31 L/s (0.7 mgd) for rural domestic and livestock uses. The public supplies were withdrawn about equally from sand and gravel aquifers and the Silurian-Devonian aquifer (Kirk et al. 1985).

Water Quality. Groundwater from the sand and gravel aquifers is hard and generally has high concentrations of iron (see Table 4.24). The TDS concentrations vary from 380 to 720 mg/L for the selected wells.

4.7.2.5 Farmland Site (Alternative D)

Hydrology. Groundwater in the Alternative D site area in north-central Livingston County mainly occurs in sand and gravel deposits in bedrock valleys and in the Glenwood-St. Peter sandstones of the Ordovician system (Selkregg and Kempton 1958). Although large yields from thicker sand and gravel deposits are possible, the water-yielding character of this aquifer varies considerably throughout the general area. The Glenwood-St. Peter unit is a dependable source of groundwater in the area; however, the water becomes highly mineralized with depth.

The water-yielding character of the Pennsylvanian rocks varies from location to location. Shallow sandstone and creviced limestone yield small supplies locally, generally less than 0.6 L/s (10 gpm) (Visocky et al. 1985). Eight wells located within 9.7 km (6 mi) of the site were tested in

Table 4.24. Water Quality Data for Selected Sand and Gravel Aquifers near the Underground Coal Mine Site

Well Location		Depth (ft)	Iron (mg/L)	Manganese (mg/L)	Fluoride (mg/L)	Chloride (mg/L)
Township, Range	Section					
15N, 10E	25	63	1.9	0.14	0.2	10.0
16N, 9E	34	72	9.7	0.0	0.3	25.0
16N, 10E	4	50	1.4	Trace	0.5	11.0
16N, 11E	31	58	1.1	0.1	0.5	5.0

Well Location		Depth (ft)	Sulfate (mg/L)	Alkalinity as CaCO ₃ (mg/L)	Hardness as CaCO ₃ (mg/L)	TDS (mg/L)
Township, Range	Section					
15N, 10E	25	63	0.0	472	364	477
16N, 9E	34	72	-	692	506	718
16N, 10E	4	50	1.0	368	267	404
16N, 11E	31	58	1.8	348	281	379

Source: Data from Kempton et al. (1982).

1934 and 1935 and were found to yield 0.3 to 0.8 L/s (4 to 12 gpm), with drawdowns of 16 to 47 m (52 to 154 ft) (Csallany 1966). The specific capacities of these wells ranged from 0.72 to 2.1 m²/d (0.04 to 0.12 gpm/ft). Water quality usually deteriorates with increasing depth (Selkregg and Kempton 1958). In Livingston County, domestic and farm water supplies are obtained from shallow Pennsylvanian formations if suitable groundwater supplies are not available from the glacial drift aquifer.

Below the Pennsylvanian System lies the Midwest Bedrock Aquigroup of Cambrian-Ordovician age. The upper part of the aquigroup comprises the Galena-Platteville Group and the Ancell Group (Glenwood-St. Peter formations). The thicknesses of these two groups at the Alternative D site are about 119 and 59 m (390 to 195 ft), respectively.

The middle part of the aquigroup is generally less permeable than the upper and lower parts. However, some dolomites and sandstones yield significant quantities of water (see Section 4.6.5). The thickness of the middle part (Knox Megagroup) is about 244 to 290 m (800 to 950 ft) in the Alternative D site area.

The lower part of the Midwest Bedrock Aquigroup is often referred to in northern Illinois as the Ironton-Galesville aquifer. These sandstones are the most uniform and productive aquifers in the Cambrian-Ordovician system in Illinois north of the Illinois River (see Section 4.6.5). This aquifer is about 61 m (200 ft) thick at the Alternative D site.

The lowest aquifer in the Cambrian System is the Elmhurst-Mt. Simon aquifer. The thickness of these sandstones in northern Livingston County has been estimated to be about 762 m (2,500 ft), based on drilling records for holes in nearby counties (Visocky et al. 1985).

Few wells tapping the Midwest Bedrock Aquigroup have been drilled in the Alternative D site area. Well yields there may vary from <6 to 32 L/s (<100 to 500 gpm), depending on the units penetrated and the geographic location (Visocky et al. 1985).

Groundwater Withdrawal. Groundwater pumping in Livingston County, estimated to be 158 L/s (3.6 mgd) in 1984 (Kirk et al. 1985), has been relatively small compared with total pumping in the northern half of Illinois. Pumpage in northern Illinois from Cambrian-Ordovician aquifers alone averaged 12,222 L/s (279 mgd) between 1971 to 1980 (Visocky et al. 1985). The total withdrawal in Livingston County consisted of 70 L/s (1.6 mgd) for public supply, 4.4 L/s (0.1 mgd) for self-supplied industries, and 83 L/s (1.9 mgd) for rural domestic and livestock uses. Of the public and industrial supplies, 66 L/s (1.5 mgd) was from glacial drift and 9 L/s (0.2 mgd) was from Cambrian-

Ordovician aquifers. Almost all of the 83 L/s (1.9 mgd) rural pumping was from the glacial drift and Pennsylvanian aquifers (Kirk et al. 1985).

Water Quality. Groundwater from the Cambrian-Ordovician aquifer in northern Illinois generally has increasing TDS concentrations to the southeast. Changes in water quality can occur rapidly over short distances as the strata dip southeastward. In the Alternative D site area, TDS concentrations are about 1,100 mg/L in the Galena-Platteville aquifer, 1,000 to 1,500 mg/L in the Ancell aquifer, 2,000 mg/L in the Ironton-Galesville aquifer, and 5,000 to 6,000 mg/L in the upper 61-91 m (200-300 ft) of the Elmhurst-Mt. Simon aquifer (Visocky et al. 1985).

4.8 ECOLOGY

The five alternative disposal sites for Kerr-McGee wastes lie within the Bluestem Prairie, Oak-Hickory Forest Mosaic (Northern) subsection (DuPage and Livingston counties) or the Oak-Hickory Forest (Northern) subsection (Douglas, Fulton, and Peoria counties) of the Prairie Parkland Province (Bailey 1978; Galvin 1979). The Oak-Hickory Forest subsection varies from dense to open woodland, ranging from riparian to upland timber dominated by oaks and hickories. However, little undisturbed habitat remains in the counties of interest because much of the land has been cleared for farming and timber production (Galvin 1979). The Bluestem Prairie, Oak-Hickory Forest Mosaic subsection is a transitional zone between deciduous forest and prairie. Historically, this area consisted of dense to open riparian woodlands interspersed with tallgrass prairies, but it is now largely cropland, with wooded areas occurring in the riparian and poorly drained areas (Galvin 1979).

4.8.1 West Chicago Site (Proposed Action)

4.8.1.1 Terrestrial

Because of its urban location and industrial use, the West Chicago site has vegetation typical of an early stage of succession. The vegetation consists of a mixture of prairie species, disturbance-related aggressive species, and remnants of landscape plantings (FES--Sec. 4.9.1.1). Although some trees (maple, cottonwood, willow, pine) and shrubs occur at the site, grasses and forbs predominate (FES--Sec. 4.9.1.1). Plants common to early-successional/disturbed sites are listed in Appendix D, Table D.5. Such species include those whose habitats are roadsides, fields, waste grounds, ditches, lawns, thickets, along railroads, and fencerows. Some of the more common grass and forb species associated with marshes and banks could occur around the ponds and in the moist areas at the West Chicago site. The FES (Appendix C, Table C.1) contains an abridged list of common plant species.

A number of reptile and amphibian species live in habitats typical of those found at the West Chicago site (Appendix D, Table D.2). However, only those species more adaptable to urban encroachment would likely be found at the site, including the American toad, leopard frog, plains garter snake, and western fox snake.

Certain resident, seasonal, and migrant bird species are expected to occur at the West Chicago site (Appendix D, Table D.1). The most abundant species would be those adapted to suburban/urban locations and associated with field/cultivated, lawn/urban habitats. These species include pigeon, sparrow, robin, crow, grackle, starling, and mourning dove. Several waterfowl species are also expected to occur in association with the on-site ponds.

Mammals known or expected to occur at the West Chicago site include small- and medium-sized species associated mostly with field/urban habitats (Appendix D, Table D.3). The most abundant species would include the white-footed mouse, short-tailed shrew, house mouse, eastern cottontail rabbit, and Norway rat.

4.8.1.2 Aquatic

The aquatic biota occurring on-site and in the vicinity of the West Chicago site were detailed in the FES (Sec. 4.9.2.1). On-site biota consist primarily of species associated with small permanent and temporary ponds. Duckweed and cattail are the predominant aquatic macrophytes. Fish are not assumed to occur at the West Chicago site because of (1) inaccessibility of the ponds to fish colonizers, (2) past dredging and draining activities, and (3) current and past chemical stresses. An abundant, but nondiverse, benthic invertebrate fauna was noted in a reconnaissance survey of the on-site ponds (FES--App. E, Table E.1). The most abundant species were those tolerant to environmental extremes of temperature, acidity, alkalinity, dissolved oxygen, and organic enrichment.

The aquatic habitats in the vicinity of the West Chicago site (i.e., Kress Creek and the West Branch DuPage River) contain a poor-quality fishery because of agricultural and urban pollution (FES--Sec. 4.9.2.1). The most numerically abundant fish species (green sunfish, bluntnose minnow, spotfin shiner) are those tolerant or moderately tolerant to conditions of habitat abuse such as organic enrichment and sedimentation. Benthic invertebrate composition in these streams is limited and classified as severely polluted.

4.8.1.3 Threatened and Endangered Species

The only federally listed species that may occur in DuPage County is the endangered Indiana bat (Myotis sodalis) (U.S. Fish Wildl. Serv. 1980). This

species primarily inhabits riparian forests during spring and summer and overwinters in mines and caves (Nat. Land Inst. 1981); it also inhabits man-made structures in summer (Burt and Grossenheider 1964). Nevertheless, the Indiana bat has not been reported in DuPage County (Nat. Land Inst. 1981), and its habitat preferences do not strongly coincide with the habitat at the West Chicago site. In northern Illinois, the federally endangered bald eagle (Haliaeetus leucocephalus) is generally a rare migrant and winter resident (Nat. Land Inst. 1981); however, its requirement for undisturbed roosting and nesting sites precludes its occurrence at the West Chicago site. No state-listed animal species are known to occur in DuPage County (Nat. Land Inst. 1981).

A number of state-listed plant species are known, at least historically, to occur in DuPage County (Appendix D, Table D.6), but only a few of these have extant populations in the county (Appendix D, Table D.7). On the basis of habitat preferences or known locations of the species (Appendix D, Table D.7), it is doubtful that any of the species occur at the West Chicago site.

4.8.2 Active Surface Coal Mine (Alternative A)

4.8.2.1 Terrestrial

Generally, the habitats within an active surface coal mine would be disturbed by the mining process and associated activities (e.g., spoils pile placement, coal storage, and coal handling). Surface mining destroys vegetation within the mined area and deposits spoils material on adjacent vegetation (Dvorak et al. 1977). Only a sparse plant community can establish itself within such areas. This community would mostly include hardy grasses and forbs that readily invade highly disturbed areas and waste grounds. Examples of such species are listed in Appendix D, Table D.5, and include those species whose habitats are listed as waste grounds. A more diverse plant assemblage would exist on older spoils piles or reclaimed portions of the mine. The species assemblage in these areas would be similar to that described for the West Chicago site (see Section 4.8.1.1). Vegetative communities surrounding the active coal mine site range from cultivated farmlands to woods. Species typifying various habitats (e.g., fields, woods, and roadsides) can be determined from habitat data given in Appendix D, Table D.5.

The active mine site is sufficiently disturbed to suffer limitations as suitable wildlife habitat. The older spoils piles and areas surrounding the active mine site represent open-land habitats and, to a much lesser extent, woodland habitats. The open-land habitats would support herpetofauna, birds, and mammals similar to those described for the West Chicago site (see

Section 4.8.1.2); however, they would contain a more diverse assemblage because many of the limiting factors associated with urban encroachment would not be present. Species that can be expected to occur in wooded habitats surrounding the active surface coal mine can be derived from habitat data in Appendix D, Tables D.1, D.2, and D.3.

4.8.2.2 Aquatic

Aquatic biota can be found in a number of habitats within and near the active surface coal mine. On-site aquatic habitats include temporary to permanent marshy areas found mainly between spoils piles. These areas are more prevalent in places where the headwater drainage of vicinity streams originates. The more obvious on-site aquatic habitats consist of a number of final-cut strip mine lakes. Nearby aquatic habitats consist mainly of several streams (Coal, Swegle, and Littlers creeks) and their intermittent or permanent tributary streams.

Biota occurring in on-site aquatic habitats (including wetland habitats) vary depending on a number of factors, but especially on permanence of water, size of water body, and water-quality conditions. A number of macrophytes are expected to occur in shallow areas of strip mine lakes and especially in wetland areas that have at least marginally good water quality. These plants include the more common species listed in Appendix D, Table D.5, whose habitats are listed as shallow water and marshes. In aquatic and wetland areas that are more stressed (e.g., by acid drainage), cattails would probably be the only dominant macrophyte.

Fish species common to smaller rivers, streams, lakes, and ponds are listed in Appendix D, Table D.4. This list was compiled from the distributional maps and habitat data of Smith (1979); thus, in most instances, the number of species that may occur in any one water body is overestimated. This is especially true for ephemeral streams where only a few species of minnows, and possibly suckers and sunfish, are expected to occur during periods of flow (Slack 1955; Larimore et al. 1959; Clifford 1966). Nevertheless, the list indicates species that are expected to occur at and in the vicinity of the active surface coal mine site.

The species composition of other major biotic communities (e.g., plankton and benthos) is expected to vary, depending on the physical and chemical characteristics of the water bodies, including influences from mining and agriculture. For example, benthos of ephemeral streams probably consist of species that have short life cycles, are adapted to survive periods of dessication, or are small enough to burrow into the substrate.

4.8.2.3 Threatened and Endangered Species

Two federally listed species may occur in Fulton County (Nat. Land Inst. 1981). These include the Indiana bat, which has a range that encompasses Fulton County, and the bald eagle, which is a common migrant and winter resident along the Mississippi and Illinois rivers. However, habitat that exists at and immediately adjacent to an active coal mine is not amenable to either species (see Section 4.8.1.3). The only state-listed animal species reported from Fulton County are the endangered American bittern (*Botanus lentiginosus*) and the endangered upland sandpiper (*Bartramia longicauda*). Habitat preferences of the American bittern -- freshwater and brackish marshes and marshy lakeshores (Nat. Land Inst. 1981) -- do not coincide with optimal areas for siting wastes at an active surface mine. However, in some instances, pooled or marshy areas do develop in depressions between spoils piles. The habitat preferences of the upland sandpiper -- dry prairies, prairie ridges with shorter grasses, burnt meadows, and grasslands adjacent to airports (Peterson 1947; Nat. Land Inst. 1981) -- are somewhat equivalent to areas that could occur at an active surface coal mine. In particular, such habitats would include older spoils or topsoil piles that have developed vegetation.

As was true for the West Chicago site, a number of state-listed plant species are historically known from Fulton County (Appendix D, Table D.6), but only a few species have extant populations (Appendix D, Table D.7). On the basis of habitat requirements or known population locations (Appendix D, Table D.7), the species are not expected to inhabit lands associated with active surface coal mines.

4.8.3 Reclaimed Surface Coal Mine (Alternative B)

4.8.3.1 Terrestrial

The terrestrial flora occurring at and near reclaimed surface coal mines is expected to be very similar to those described for active surface coal mines (see Section 4.8.2.1). The primary difference would be that the expanse of habitat preempted by mining-related activities at an active surface coal mine would not occur at a reclaimed surface coal mine. Most of the area occupied by a reclaimed surface coal mine consists of fieldlike habitat composed of tall grasses and forbs. This habitat would include a diverse array of species (e.g., many of the species listed in Appendix D, Table D.5, except for those associated with wooded habitats).

Terrestrial fauna inhabiting a reclaimed surface coal mine and surrounding areas would also be similar to those described for the older spoils piles and areas adjacent to an active surface coal mine (see Section 4.8.2.1).

4.8.3.2 Aquatic

As with the active surface coal mine site, the aquatic habitat at the reclaimed surface coal mine consists of a number of final-cut strip mine lakes and marsh habitats on-site and small streams on-site and off-site (West Fork of Kickapoo Creek and its tributaries). Because of the similarity of habitats and the close geographic proximity between the reclaimed and active surface mines, it can be concluded that the aquatic biotic composition described in Section 4.8.2.2 would also apply to the reclaimed surface coal mine site.

4.8.3.3 Threatened and Endangered Species

The description of threatened and endangered animal species for active surface coal mines (see Section 4.8.2.3) also applies to the reclaimed surface coal mine. However, the state-listed bird species have not been reported from Peoria County (Nat. Land Inst. 1981).

The state threatened and endangered plant species that have been historically known to occur in Fulton and Peoria counties are listed in Appendix D, Table D.6. Species with extant populations in the counties are listed in Appendix D, Table D.7. Habitat preferences or known population localities preclude their probable occurrence at reclaimed coal mines. However, conditions that exist in some areas of reclaimed coal mines (e.g., final-cut lakes or wetlandlike habitats between revegetated spoils piles) could potentially be inhabited by a few of the species, such as Scirpus paludosus, Artemisia dracunculus, and Filipendula rubra.

4.8.4 Underground Coal Mine (Alternative C)

4.8.4.1 Terrestrial

The habitats in the vicinity of the underground coal mine are mostly farmlands (i.e., cultivated and fallow fields and pastures), which are intermingled with woodlots and fencerows. Wooded riparian habitat occurs along Brushy Fork. Much of the habitat at the mine site is essentially destroyed or occupied by mine-related activities and facilities (e.g., slurry pond, gob pile, coal storage area, and coal handling facilities). Vegetation in the area mostly consists of species (primarily grasses and forbs) whose habitats are fields, roadsides, waste grounds, and prairie soils (see Appendix D, Table D.5). Species with habitats listed as thickets, fencerows, wood edges, and open woods are also expected in such areas near the mine site. Woody species such as aspen, buckthorn, gooseberry, hawthorn, willow, and viburnum would occur in riparian areas along Brushy Fork.

A few reptile and amphibian species common to the drier above-mentioned habitat types (Appendix D, Table D.2) would be found at and around the underground coal mine site. Among the more prevalent species would be the American toad and the eastern garter snake. A more diverse assemblage of bird species would also be found in these habitats. Nearly all species listed in Appendix D, Table D.1, are expected to occur, although those species with habitats listed as woods would only rarely be observed. A number of mammal species would also inhabit the area (Appendix D, Table D.3); the more commonly occurring mammals would be the opossum, short-tailed shrew, eastern mole, thirteen-lined ground squirrel, deer mouse, and eastern cottontail rabbit.

4.8.4.2 Aquatic

Aquatic habitats in the vicinity of the underground coal mine include tributaries of Brushy Fork and Jordan Slough and several small ponds. Wetland habitats are mostly marshes and wet meadows. Vegetation in such habitats would include those species listed in Appendix D, Table D.5, whose habitats include marshes, banks, and shallow water. As with the drier sites, the aquatic habitats would consist mostly of grass and forb species.

A large number of reptile and amphibian species (especially frogs and turtles) would be expected to occur in association with the aquatic and wetland habitats (Appendix D, Table D.2). Most bird species listed in Appendix D, Table D.1, are expected to occur near water bodies and wetlands. Waterfowl and shorebirds would be the most commonly occurring ones (e.g., species with habitats listed as ponds, marshes, and streams). Several mammal species -- such as the long-tailed weasel, mink, striped skunk, meadow vole, and especially the muskrat -- would be more common near the aquatic habitats. A number of fish species would occur in the tributary streams and ponds near the underground coal mine. These species would potentially include any of those listed in Appendix D, Table D.4, whose range includes Douglas County. However, the number of species that would occur in any one water body would undoubtedly be less than the number of species listed in Table D.4.

4.8.4.3 Threatened and Endangered Species

No threatened or endangered animal species have been reported from Douglas County, and Panax quinquefolius (ginseng) is the only state-listed (threatened) plant species reported (Nat. Land Inst. 1981). On the basis of its habitat preference for rich and moist woodlands, ginseng could occur in undisturbed areas overlying or adjacent to an underground coal mine. Although not reported from Douglas County, the range of the Indiana bat encompasses the county. Forested areas surrounding the mine could be used by the bat during spring and summer. The bald eagle could also be a rare migrant or winter

resident in Douglas County; however, lack of suitable habitat, along with disturbance activities at the mine site, precludes its occurrence at the underground coal mine site.

4.8.5 Farmland Site (Alternative D)

4.8.5.1 Terrestrial

The terrestrial biota associated with the farmland site would be similar to those described for the underground coal mine site (see Section 4.8.4.1). However, the biotic composition would be somewhat more diverse and abundant for the farmland site because the land would not have been disturbed or preempted by mine-related activities. Farmlands, especially unused areas, can support a diverse plant assemblage (Appendix D, Table D.5) and associated fauna (Appendix D, Tables D.1, D.2, and D.3).

4.8.5.2 Aquatic

Aquatic habitats, including wetlands, bordering the farmland area potentially include tributaries to the Vermillion River, small farm ponds, marshes, and wet meadows. Biota associated with these habitats would be essentially similar to those in the vicinity of the underground coal mine site (see Section 4.8.4.2).

4.8.5.3 Threatened and Endangered Species

No federally or state listed animal species are reported from Livingston County, although species occurring in LaSalle County could possibly cross over into the county. The endangered Indiana bat is the only federally listed species reported to occur in LaSalle County (Nat. Land Inst. 1981). Its habitat preferences have been described in Section 4.8.1. Spring and summer habitat could include forested areas or shelterbelts that often occur within unused areas of farmlands. The likelihood of this is enhanced by the fact that the only definite winter colony of Indiana bats within Illinois occurs in Blackball Mine in LaSalle County (Nat. Land Inst. 1981). The endangered bald eagle could also be a rare migrant or winter resident within Livingston County (Nat. Land Inst. 1981); however, its habitat requirements do not correspond with farmland habitat. State-listed animal species that occur in LaSalle County are the endangered upland sandpiper and the endangered marsh hawk (Circus cyaneus) (Nat. Land Inst. 1981). Habitat preferences of the upland sandpiper are described in Section 4.8.2.3. The marsh hawk nests in large, undisturbed marshes; sedge meadows; and wet prairies (Nat. Land Inst. 1981). Breeding sites have been reported in LaSalle County. However, those habitats do not coincide with the drier sites that would be preferred for disposal of

wastes on farmlands. However, the marsh hawk does hunt over pastures and fallow fields, both of which coincide with the farmland site.

Only one state-listed plant species (Carex intumescens) has been reported in Livingston County (Appendix D, Table D.6); however, an extant population of this species is not currently known in the county (Nat. Land Inst. 1981).

4.9 EXISTING RADIOLOGICAL ENVIRONMENT

Radiation in the environment from background sources is frequently used as a baseline for comparison with radiation from various man-made sources. Background radiation derives from cosmic sources, external terrestrial sources, and internally deposited radionuclides. To assist in assessing the radiological implications at the potential sites for disposal of the Kerr-McGee wastes, the existing radiological environments at the different sites and the associated radiation doses are described in this section.

4.9.1 West Chicago Site (Proposed Action)

The West Chicago site is located about 48 km (30 mi) west of Chicago. The annual external dose for Chicago is about 41 mrem from terrestrial sources, 45 mrem from cosmic radiation, 5 mrem from weapons test fallout, and 2 mrem from other sources (Natl. Counc. Radiat. Prot. Measure. 1975; Kathren 1984). Internally deposited radionuclides would contribute an additional 20 mrem/yr, mainly from potassium-40 (Kathren 1984), and the dose from radon and its short-lived daughters would add another 90 mrem/yr (U.N. Sci. Comm. Effects At. Radiat. 1982). Therefore, the total effective dose equivalent from all these background sources would be about 200 mrem/yr.

Measurements taken near the West Chicago site boundary indicate that elevated readings at many off-site locations result from radioactive contaminants in the ground at those locations rather than from direct radiation from the tailings piles at the West Chicago site. Measurements using thermoluminescent dosimeters indicate that background radiation levels related to external radiation are not above the variations to be expected from background sources of radioactivity; average exposure rates at the junior and senior high schools were 8.5 and 10.7 $\mu\text{R/h}$, respectively. These rates are comparable to exposure rates of 14.7 $\mu\text{R/h}$ for Chicago, 7.8 $\mu\text{R/h}$ for Illinois, and 4.2 to 9.1 $\mu\text{R/h}$ for the Midwest (Natl. Counc. Radiat. Prot. Measure. 1975; Kathren 1984).

4.9.2 Alternative Disposal Sites

Because of their geographical closeness (see Section 4.1), the four alternative Illinois sites for disposal of the Kerr-McGee wastes are expected to have similar background radiation levels. The annual average external dose for the state of Illinois is about 65 mrem from external radiation and 45 mrem from cosmic radiation (Nat'l. Council. Radiat. Prot. Measure. 1975; Kathren 1984). The U.S. average dose from other external background radiation (e.g., weapons test fallout and other minor sources) is about 7 mrem/yr. The dose contribution from internally deposited radionuclides and from background sources of radon in Illinois is similar to that in the Chicago area, about 110 mrem/yr. The effective dose equivalent from all these sources totals about 230 mrem/yr.

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*In this reference list, (1) the term "personal communication" is used to indicate either a telephone conversation or a face-to-face conversation and (2) all letters and memos cited are on file. Copies are available upon request from S.Y. Tsai, Energy and Environmental Systems Division, Bldg. 362, Argonne National Laboratory, Argonne, Illinois 60439.

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5. ENVIRONMENTAL CONSEQUENCES

5.1 TOPOGRAPHY

5.1.1 Description of Impacts

5.1.1.1 West Chicago Site (Proposed Action)

Disposing of the Kerr-McGee wastes at the West Chicago site would alter the site topography and cause minor changes in existing drainage patterns. The Factory and Intermediate sites would be filled and graded to blend in with the surrounding residential areas. The completed disposal cell would appear as a flat-topped hill and would stand about 12 m (40 ft) above the surrounding grade level. Excavation of clay materials from an off-site borrow pit would create a permanent, shallow surface depression somewhere near West Chicago.

5.1.1.2 Active Surface Coal Mine (Alternative A)

If Alternative A were implemented, the Kerr-McGee wastes would be buried in a deep-trench disposal cell at an active surface coal mine. The Alternative A disposal cell would have a surface cap slightly higher than the surrounding area to divert surface water away from the cell. However, the disposal cell ridge should blend into the surrounding terrain and not be particularly noticeable because this area has slightly rolling topography. After the contaminated materials and soils were excavated and removed from the West Chicago site, clean fill material would be brought in from off-site and the area would be restored to approximately the same elevation as the surrounding terrain.

5.1.1.3 Reclaimed Surface Coal Mine (Alternative B)

If the Alternative B disposal option were implemented, the Kerr-McGee wastes would be buried in a deep-trench disposal cell at a reclaimed surface coal mine. The upper surface of the cell cap would be slightly higher than the surrounding terrain to promote positive surface runoff, but the disposal cell should blend into the surrounding landscape because this area has slightly rolling topography. Nearby spoil hills (see Figure 3.5) would be used to fill the upper part of the pit and to construct the disposal cell cap. Thus, no off-site borrow pit would have to be excavated, but the spoil hills and lake would be removed. After the contaminated materials and soils were excavated and removed from the West Chicago site, clean fill material would be brought in from off-site and the West Chicago site would be restored to approximately the same elevation as the surrounding terrain.

5.1.1.4 Underground Coal Mine (Alternative C)

If the Alternative C disposal option were implemented, the Kerr-McGee wastes would be disposed of in the workings of an underground coal mine. Deep underground disposal would not raise the land surface. Moreover, placement of the wastes in the mine workings should partially support the mine roof and reduce the chances of mine subsidence, which is a positive impact. A temporary surface storage pile might have to be created near the unloading area (truck or rail) to accommodate the wastes prior to transport and placement underground. After the contaminated materials and soils were excavated and removed from the West Chicago site, clean fill material would be brought in from off-site, and the area would be restored to approximately the same elevation as the surrounding terrain.

5.1.1.5 Farmland Site (Alternative D)

If the Alternative D disposal option were implemented, an above-grade disposal cell would be constructed for the Kerr-McGee wastes at a farmland site. The completed cell would cover an area of about 19 ha (47 acres), and its upper surface would be about 7.6 m (25 ft) above the existing land surface. The disposal cell would lie on the crest of a glacial moraine but not at its highest elevation. The upper surface of the disposal cell should be at about the same elevation, or slightly lower, than the high areas of the moraine; hence, it should blend into the surrounding topography. During construction of the disposal cell, temporary storage piles would be created to store glacial till, loess, and topsoil that would be scalped off the surface of the disposal cell site. These materials would be used to construct the cell berm and cap. The storage piles would be temporary and would not exist after cell construction is complete. After the contaminated materials and soils were excavated and removed from the West Chicago site, clean fill material would be brought in from off-site and the area would be restored to approximately the same elevation as the surrounding terrain.

5.1.2 Mitigative Measures

If the Kerr-McGee wastes were contained at the West Chicago site in an above-grade disposal cell, a high mound would exist. Possible mitigative measures would be to choose a different disposal site. Choosing a different disposal site is not warranted solely because of minor "topographic impact." The same argument can be made for the other above-grade disposal alternative, the farmland site (Alternative D). No permanent changes in topography would result from deep-trench disposal at the active or reclaimed surface coal mines (Alternatives A and B) or from disposal in an underground coal mine (Alternative C).

5.2 AIR QUALITY

5.2.1 Description of Impacts

Suspended particulate matter is the principal pollutant of concern with regard to air quality. In addition, ground-level concentrations of sulfur dioxide, nitrogen dioxide, and carbon monoxide would increase because of the operation of internal-combustion engines of heavy-duty vehicles.

If on-site disposal of the Kerr-McGee wastes were undertaken, emissions would increase because of the heavy equipment used to transport the wastes and the earth-moving equipment used to landscape the site. Equipment such as bulldozers and front-end loaders would be the main factor in the resuspension of particulates, whereas operation of diesel engines of heavy-duty vehicles would be the main source of gaseous pollutants such as sulfur dioxide, carbon monoxide, nitrogen dioxide, and lead.

The EPA-approved Industrial Source Complex (ISC) dispersion model (Bowers et al. 1979) was used to calculate pollutant concentrations. The ISC short-term program, which is a modified version of the EPA single-source model known as CRESTER, was used to compute pollutant concentrations and to average periods from 1 to 24 hours. The ISC long-term program is a combination of the EPA Air Quality Display Model (AQDM) and the EPA Climatological Dispersion Model (CDM); it was used to compute seasonal and annual averages.

The meteorological data used were hourly average values of surface observations obtained from the National Climatic Center for sites at O'Hare Airport and Peoria from December 1, 1980, to December 31, 1985. The data used in the current calculations included wind speed, wind direction, temperature, and cloud cover. The inversion height was assumed to be 200 m (656 ft), which is about the smallest value to be expected in normal daytime conditions, and using this inversion height should result in conservative estimates of pollutant concentrations. It should not significantly affect estimated pollutant concentrations near the ground because the emissions occur near the surface and the vertical dimension of the plume is not expected to be affected significantly within the short distances being considered in the current analysis.

Pollutant emissions were derived by assuming 21.8 MT of wastes per truckload and 23,500 truckloads (see Section 5.9.2) transported in 420 8-hour workdays. The trucks were assumed to travel at 16 km/h (10 mph). Emission factors, in grams per vehicle-mile, are 1.3 for particulates, 2.8 for sulfur dioxide, 28.7 for carbon monoxide, 20.9 for nitrogen dioxide, and 0.0025 for lead; the particulate emission rate for site work is assumed to be 0.018 kg per metric ton of truckload (U.S. Environ. Prot. Agency 1985). The estimated

emissions data used in the current model calculations are shown in Table 5.1. The waste-disposal operation is assumed to be carried out mainly in a circular area with a radius of 200 m (660 ft), which is about the size of the disposal area in West Chicago. To simplify the calculations, all point sources are assumed to be stationary and located at the center of the area. This assumption is expected to result in pollutant concentrations being over-estimated because most of the sources are mobile.

In the model calculations, the particulate emissions given in Table 5.1 were further reduced by 50%, assuming that water would be sprayed over the ground surface and the waste pile. The particle-size distribution was estimated from PEDCo Environ./TRC Environ. Consult. (1982). The mass distribution versus the range of particle diameters is 14.6% for 0 to 5 μm , 19.4% for 5 to 10 μm , 14.6% for 10 to 15 μm , 23.9% for 15 to 30 μm , and 27.5% for 30 to 100 μm .

Table 5.1. Emissions Data Used in Predicting Pollutant Concentrations during Waste-Disposal Operations

Pollutant	Source	Source Type	Strength [g/s for point; g/(s·m ²) for area]	Source Diameter (m)	Source Height (m)
TSP	Site work	Area	1.98×10^{-5}	200	2
TSP	Wind erosion	Area	3.15×10^{-6}	200	1
Sulfur oxides	Diesel engine	Point	1.10×10^{-1}	2	3
Carbon monoxides	Diesel engine	Point	1.60×10^{-1}	2	3
Nitrogen oxides	Diesel engine	Point	8.40×10^{-1}	2	3
Lead	Diesel engine	Point	8.04×10^{-4}	2	3

Pollutant concentrations were computed for the shortest distance from the disposal site to the plant boundary of the West Chicago site, which is about 100 m (330 ft). This distance was also assumed for the other sites in this analysis. This assumption is expected to give more conservative estimates for other sites because they are located in far more remote areas where more land is available than at the West Chicago site. The estimated total pollutant concentrations at the site boundaries during disposal operations are presented in Table 5.2.

Table 5.2. Estimated Total Pollutant Concentrations from Waste-Disposal Operations^a

Site	TSP ($\mu\text{g}/\text{m}^3$)		Sulfur Dioxide ($\mu\text{g}/\text{m}^3$)			Nitrogen Dioxide ($\mu\text{g}/\text{m}^3$)	Carbon Monoxide (mg/m^3)		Lead ($\mu\text{g}/\text{m}^3$)
	Annual	24-hour	Annual	24-hour	3-hour	Annual	8-hour	1-hour	Quarterly
West Chicago site ^b	45.4	115.2	17.8	81.0	222.0	37.0	6.3	13.8	0.25
Rapatee and Elm mines	38.9	118.6	27.6	164.4	300.4	-	8.4	19.1	0.32
Murdock mine	34.6	104.6	18.5	163.9	301.7	-	9.2	14.5	-
Farmland site	45.4	130.2	26.4	113.0	231.4	-	6.3	13.8	0.20
State and federal primary standards	75	260	80	365	None	100	10	40	1.5
State and federal secondary standards	None	150	None	None	1,300	100	10	40	1.5

^a The values were obtained by summing the ambient values given in Table 4.4 and the predicted increases related to waste disposal; for averaging periods less than or equal to 24 hours, the values given are the second highest.

^b These results represent on-site disposal. If off-site disposal were chosen, the air quality impacts should be less than the values given here for the West Chicago site.

Source: Illinois Environmental Protection Agency (1985).

The results indicate that the impact of waste-disposal operations on air quality would be rather insignificant. Comparison of Tables 4.4 and 5.2 indicates that no new violations of the standards would be created by the disposal operations. The increases in 24-hour average values of TSP due to contributions from the waste-disposal operation would range from $1.6 \mu\text{g}/\text{m}^3$ for Murdock to $5.6 \mu\text{g}/\text{m}^3$ for Rapatee. The concentrations of sulfur dioxide, nitrogen dioxide, and lead would all be much lower than the standards. Based on the 1984 ambient data, the 8-hour average value of carbon monoxide at the Rapatee and Elm mines would exceed the standard, but these mines are located in nonattainment areas where the standard would be violated even before the waste-disposal operations were undertaken. Moreover, the contribution from disposal of the Kerr-McGee wastes would be only $0.7 \text{ mg}/\text{m}^3$. Because the increase is insignificant and the operations would be temporary, all state officials contacted indicated that a permit would normally be granted for the operations. However, based on 1985 and 1986 data for the 8-hour average value of carbon monoxide, the standard would be met because $7.7 + 0.7 = 8.4 \text{ mg}/\text{m}^3$, which is less than the standard of $10 \text{ mg}/\text{m}^3$.

5.2.2 Mitigative Measures

The rates at which gaseous pollutants are emitted and particulates are resuspended can be regulated by varying the rate at which the wastes are processed. For example, if the period of waste removal were extended by a factor of two, then the pollutant emission rates would be reduced by the same factor. Particulate emission rates also vary with the moisture content of the material being loaded or unloaded, the type of vehicle, the method of loading or unloading, the wind speed, and the efficiency of any control techniques used. Dust can be suppressed during loading by wetting the material with water or chemical suppressants and by limiting the free-fall distance if using a gravity-loading technique. Loading and unloading of wastes should be avoided during high wind conditions.

During transportation, the waste materials should be covered with a tarpaulin or canvas to reduce emissions. At the disposal site, vehicle speeds should be reasonably slow, particularly during dry conditions, to minimize the production of fugitive dust when traveling over unpaved roads.

Both gaseous and particulate emissions, particularly those resulting from diesel fuel combustion, can also be reduced by using newer-model vehicles that are equipped with better pollution-control devices.

5.3 SOCIOECONOMIC

5.3.1 Description of Impacts

5.3.1.1 Demography

Trends in population growth for DuPage County and the city of West Chicago are not expected to change as a result of implementing the on-site disposal alternatives. However, because the West Chicago site is located in a densely populated area with several schools nearby, the likelihood of humans intruding into the area is high -- certainly higher than for any of the other alternatives.

Trends in population growth for the counties containing the alternative sites, and for cities and towns near the sites, are not expected to be affected by disposal of the Kerr-McGee wastes. However, the potential for human intrusion into the disposal area is considered to be less at the alternative sites than at the West Chicago site because of the location of the off-site alternatives in more sparsely populated rural areas.

5.3.1.2 Transportation

Transportation problems associated with the waste-disposal operations would include periodic road closings, traffic congestion, dust, noise, and road damage. Such adverse impacts would be less severe for on-site disposal than for off-site disposal because less transportation would be required. Transporting the wastes off-site by truck would result in such problems, but, because the counties containing the alternative sites are sparsely populated, transportation-related impacts at the disposal sites would be small and could be mitigated. Transportation problems at the West Chicago site would be greater for any of the off-site disposal alternatives than for on-site disposal because more trucks would be needed to transport the wastes off-site.

5.3.1.3 Property Values

Previous research on the property values of residences in the vicinity of the West Chicago site indicates that there were verifiable negative effects on the selling prices of older homes within a two-block radius of the site from 1978 to 1982 (Payne et al. 1987). It is not known whether such trends have continued past 1982. Although it is difficult to determine precisely what aspects of a given community contribute to increases or decreases in the value of individual homes, the data suggested in this case that the negative publicity associated with the Kerr-McGee facility contributed to the observed effect. It is reasonable to expect that the activities associated with either on-site stabilization or removal to an alternative site would have a

short-term negative impact on local property values. However, in the long term, either action would be expected to have a positive impact on local property values.

In the case of off-site disposal, it is difficult to determine the impact on property values in the vicinity of any of the alternative sites because of the limited number of property transactions that occur in these areas. Although it is reasonable to expect that there would be some negative impact on local property values at an alternative site, these impacts would be minimal because of the limited number of people affected.

5.3.1.4 Taxes

Currently, less than 0.002% of all taxes collected in DuPage County are contributed by Kerr-McGee Chemical Corporation for its West Chicago facility (Table 4.7). Whether this percentage would change with on-site disposal depends on the future use and ownership of the land.

With the removal of the Kerr-McGee wastes from the West Chicago site, the area could eventually be returned to private use. The value of the property might increase, and the property might eventually contribute significantly to the local tax base -- depending on the future ownership and use of the land. The tax bases of the counties in which the alternative sites are located should not be influenced by the presence of a waste-disposal facility.

5.3.2 Mitigative Measures

5.3.2.1 Demography

The main problem related to population near the West Chicago site and the alternative sites is the potential for human intrusion into the disposal area. With on-site disposal, this potential would be increased because of the higher population density of the West Chicago site. For this alternative, the probability of human intrusion should be minimized by fencing the disposal area and providing periodic monitoring and maintenance.

The potential for human intrusion is less for off-site disposal, but precautionary measures should be implemented to minimize the possibility of its occurrence. The disposal area should be fenced and the site should be provided with periodic monitoring and maintenance.

5.3.2.2 Transportation

With on-site disposal, transportation problems would be concentrated in the West Chicago area at the Kerr-McGee facility. Problems of noise, dust,

and traffic would be reduced considerably by timing the work so that it did not conflict with local heavy traffic patterns and by using standard methods to control dust and noise. Any road damage occurring as a direct result of on-site disposal activities should be repaired by Kerr-McGee at its cost.

With off-site disposal, transportation problems would be concentrated at the West Chicago site, but some minor transportation problems could also be expected at the off-site disposal sites. Problems of noise, dust, traffic, and road damage at both sites should be resolved as discussed above.

5.3.2.3 Taxes

With on-site disposal, property taxes from the Kerr-McGee facility might increase, especially if the site were used for other purposes. Also, it is impossible for the value of the Kerr-McGee property to drop far enough to measurably affect taxes to DuPage County because assessed value is already so low. Therefore, no mitigation is required.

With disposal at any of the alternative sites, it is estimated that from 8.1 to 77 ha (20 to 190 acres) would be required for the disposal area and a fenced-in safety zone (Appendix B, Table B.3). The amount of property taxes per acre currently paid for land in the surrounding area should be used as a basis for estimating the taxes to be paid by Kerr-McGee on the land to be used for the proposed project.

5.4 LAND RESOURCES

5.4.1 Description of Impacts

For on-site disposal, the land at the West Chicago site, excluding the disposal cell, would be graded and landscaped. The disposal cell area would be graded, seeded, and then fenced to prevent human intrusion. If all of the wastes were removed from the West Chicago site, the land in that area would be restored for public use. In either case, whether the land would be sold for commercial, industrial, or residential use, or whether it would be sold at all, has yet to be determined.

Approximately 8.1 to 77 ha (20 to 190 acres) of land would be required at the off-site disposal areas for waste containment and border zones surrounding the disposal areas (Appendix B, Table B.3). After disposal, the land at the alternative site would be contoured and graded. Estimates of the land required for the off-site disposal alternatives include the additional land that would be required for site preparation and for use during disposal activities. Upon completion of disposal activities, this land would be graded, contoured, and restored to look like the surrounding area.

5.4.2 Mitigative Measures

With on-site disposal, the land currently owned by Kerr-McGee and not used for waste disposal (i.e., the Factory Site and the land immediately surrounding it) could be sold or leased for commercial, industrial, or residential use. The disposal area should be secured with high-security fencing and radioactivity warning signs, and should be maintained and monitored routinely by Kerr-McGee or a Kerr-McGee contractor. As part of maintenance, the growth of woody plants in the area should be minimized so that the high-security area would be visible from the outer perimeter of the site.

With disposal at any of the alternative sites, the required land should be purchased at the market value current at the time of purchase. The disposal area should be secured with high-security fencing and radioactivity warning signs, and maintained and monitored routinely. All of the land constituting the Kerr-McGee property in West Chicago could be sold for residential, commercial, or industrial use.

5.5 HISTORICAL AND ARCHEOLOGICAL

5.5.1 Description of Impacts

None of the alternative disposal sites is currently known to contain significant cultural resources sites (i.e., those eligible for inclusion in the National Register) that would be adversely affected by the proposed action. However, confirmation by a systematic, on-ground survey conducted by a professional archeologist (including an inventory and documentation of historic structures) would probably be necessary in order for the State Historic Preservation Officer to issue a "determination of no effect." Only the West Chicago site and the underground coal mine alternative would be potentially exempt from the survey requirement; the former because it would entail health risks, and the latter because it would involve minimal impacts to any archeological or historic sites in the area.

5.5.2 Mitigative Measures

Adverse impacts to any significant cultural resources sites discovered during the survey could likely be mitigated through avoidance, that is, minor modifications in the location of the disposal site. However, it would be necessary for the applicant to develop a mitigation plan in consultation with the State Historic Preservation Officer and the Advisory Council on Historic Preservation.

5.6 SOILS AND GEOLOGY

5.6.1 Containment Integrity

5.6.1.1 Evaluation of Soil Erosion

As long as the disposal cell cover is maintained, the integrity of the cover should not be affected. However, if institutional control of the disposal site should cease, cover integrity could be affected by natural events such as wind, erosion, drought, and destruction of cover vegetation. Of these events, erosion has the potential for the greatest impact.

Depending upon the amount and type of vegetative cover, amount and intensity of rainfall, and soil type, a plot of land can quickly be destroyed through erosion. To demonstrate possible disposal cell erosion rates, annual erosion rates were calculated using the Universal Soil Loss Equation (USLE). The USLE (Wischmeier and Smith 1978) gives the average rate of erosion on a slope per unit area, excluding gully erosion. This equation, designed to calculate erosion rates from agricultural lands, has been used to calculate erosion rates from disturbed lands. The equation does not give the rate of erosion at a given point on the slope and does not give the erosion rate for nonuniform slopes.

The average rate of erosion is given by:

$$A = RKLSCP \quad (5.1)$$

where A = erosion rate (tons/acre/year), R = rainfall factor, K = erodibility factor,* L = slope length factor, S = slope steepness factor, C = vegetation cover factor, and P = support practice factor. The L factor = $(\lambda/72.6)^m$, where λ = length of slope (ft) and m = 0.5 for slopes $\geq 5\%$ and 0.3 for 1-3% slopes; the S factor = $65.41\sin^2\theta + 4.56\sin\theta + 0.065$, where θ = slope angle; and the P factor = 0.5 for maintained land use and 1.0 for unmaintained land use. The parameter values used are presented in Table 5.3.

For this analysis, annual erosion rates were calculated for maintained and unmaintained disposal cell covers (Table 5.4). Maintained land uses are defined as either grasses and hay or a natural rotation of row crops and hay; unmaintained land uses are defined as either pioneer forest with grasses and shrubs or mature forest.

*Erodibility factor (K) values are normally presented for undisturbed soil. Barfield et al. (1983) point out that no information is available on the K value of exposed spoil material or for topsoil that has been reconstructed. For calculations presented here, the K values are published topsoil values.

Table 5.3. Parameters Used to Calculate Erosion Rates

Alternative ^a	Material	Parameter ^b	Value	Vegetation	Land Use
Proposed Action	Topsoil	R	160		
		K	0.32		
		C*	0.016	Grasses and hay	Maintained
		C	0.074	Row crops	Maintained
		C	0.003	Pioneer forest	Unmaintained
A	Spoil	C	0.001	Mature forest	Unmaintained
		R	180		
		K	0.32		
		C*	0.016	Grasses and hay	Maintained
		C	0.074	Row crops	Maintained
B	Spoil	C	0.003	Pioneer forest	Unmaintained
		C	0.001	Mature forest	Unmaintained
		R	175		
		K	0.32		
		C*	0.016	Grasses and hay	Maintained
D	Topsoil	C	0.074	Row crops	Maintained
		C	0.003	Pioneer forest	Unmaintained
		C	0.001	Mature forest	Unmaintained
		R	170		
		K	0.32		
		C*	0.016	Grasses and hay	Maintained
		C	0.074	Row crops	Maintained
		C	0.003	Pioneer forest	Unmaintained
		C	0.001	Mature forest	Unmaintained
		R	170		

^a Proposed Action: Above-grade burial, Kerr-McGee design, West Chicago.

Alternative A: Deep-trench burial, active coal mine.

Alternative B: Deep-trench burial, inactive coal mine.

Alternative C: Underground burial (no erosion calculation).

Alternative D: Shallow burial, farmland site.

^b Source: An asterisk indicates that the data are from Lutton et al. (1979); all other data are from Barfield et al. (1983).

The calculated erosion rates were based on a number of assumptions. One assumption was that vegetation would be growing on the site in the future. Vegetation is extremely important in determining overall erosion rates because tilled soil is estimated to erode about 3,000 times faster than mature forest soil and about 100 times faster than soil under a heavy cover of grass (Barfield et al. 1983).

The estimated times required to erode the 61-cm (2-ft) thick topsoil for various vegetative types at the alternative sites are given in Table 5.5. In

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Table 5.4. Estimated Soil Erosion Rates

Alternative ^a	Material	Land Use or Vegetation	Length of Slopes (ft)		Erosion Rates (cm/yr)	
			Top	Flanks	Top	Flanks
Proposed Action	Topsoil	Grasses and hay	168-591 ^b	163-205 ^b	0.00290	0.03574
		Row crops	168-591	163-205	0.01054	0.16704
		Pioneer forest	168-591	163-205	0.00084	0.01354
		Mature forest	168-591	163-205	0.00028	0.00452
A	Spoil	Grasses and hay	180	-	0.00232	
		Row crops	180	-	0.01072	
		Pioneer forest	180	-	0.00087	
		Mature forest	180	-	0.00029	
B	Spoil	Grasses and hay	180	-	0.00225	
		Row crops	180	-	0.01042	
		Pioneer forest	180	-	0.00084	
		Mature forest	180	-	0.00028	
D	Topsoil	Grasses and hay	560	40	0.00275	0.01804
		Row crops	560	40	0.01270	0.08342
		Pioneer forest	560	40	0.00103	0.00676
		Mature forest	560	40	0.00034	0.00225

^a Proposed Action: Above-grade burial, Kerr-McGee design, West Chicago site.

Alternative A: Deep-trench burial, active surface coal mine.

Alternative B: Deep-trench burial, reclaimed surface coal mine.

Alternative C: Underground burial (no erosion calculation).

Alternative D: Shallow burial, farmland site.

^b The pile has an irregular shape. The lengths of the various sections of the top cover and flanks fall in the range indicated.

every case, the estimated lifetime of the topsoil in natural succession from pioneer forest to mature forest is very long, ranging up to tens of thousands of years on the steep flanks and up to hundreds of thousands of years on the tops of the covers. Row-crop farming would lead to very rapid erosion of the disposal cells. Cultivation of hay instead of row crops would lead to moderately slow erosion rates.

If, for some unforeseen reason, the topsoil at the site became completely eroded, the wastes would still be protected by the remaining 1.8 m (6 ft) of cover material (Section 3.2 and Appendix B, Section B.2). The layer immediately beneath the topsoil, the clay-cobblestone intruder barrier, would offer long-term protection.

Table 5.5. Estimated Erosion Times

Alternative ^a	Material	Land Use or Vegetation	Erosion Times (yr)	
			Top	Flank
Proposed Action	Topsoil	Grasses and hay	27,000	1,700
		Row crops	6,000	365
		Pioneer forest	72,000	4,500
		Mature forest	218,000	13,500
A	Spoil	Grasses and hay	26,000	-
		Row crops	6,000	-
		Pioneer forest	70,000	-
		Mature forest	211,000	-
B	Spoil	Grasses and hay	28,000	-
		Row crops	6,000	-
		Pioneer forest	72,000	-
		Mature forest	217,000	-
D	Topsoil	Grasses and hay	22,000	3,400
		Row crops	5,000	700
		Pioneer forest	59,000	9,000
		Mature forest	178,000	27,000

^a Proposed Action: Above-grade burial, Kerr-McGee design, West Chicago site.

Alternative A: Deep-trench burial, active surface coal mine.

Alternative B: Deep-trench burial, reclaimed surface coal mine.

Alternative C: Underground burial (no erosion calculation).

Alternative D: Shallow burial, farmland site.

It is not possible to determine exact erosion rates for the clay-cobblestone layer because, unlike soil conditions, precise erosion rates for rocks and minerals have not been determined. However, the erosion rates can be estimated based on published data. Reported erosion rates of limestone and other carbonate rocks range from a high rate of 2.5 cm (1 in.) in 13 years to a low rate of 1.3 cm (0.5 in.) in 1,000 years (Ollier 1969). If similar rates prevailed and limestone was used for the cobblestones, the time required to erode the 61-cm (2-ft) thick clay-cobblestone layer could range from about 300 to 47,000 years, depending on the thickness of the cobblestone in the layer. If other rock types were used for the cobblestones, such as granite or other silicate rocks that are less susceptible to erosion, the clay-cobblestone layer would have a much longer life expectancy. Although rapid erosion of rocks does occur under certain circumstances, it is believed that this is the

exception rather than the rule; and it is assumed that the clay-cobblestone layer could have a life expectancy of approximately 40,000 years.

To reduce the rate of erosion through the clay-cobblestone layer, a careful choice of cobblestone material should be made. Limestone, the most common material in the West Chicago area and much of Illinois, is highly susceptible to solution erosion, particularly if thinly bedded or fractured. If limestone were used, it should be high-grade and free of fractures and bedding planes. The life of the clay-cobblestone layer could further be extended if other rocks types were used such as granite or other silicate rocks that are less susceptible to dissolution.

Integrity of the clay layer and the clay liners beneath the disposal cells would also depend upon the type of clay used and its response to changes in the moisture and the chemical environment within the cells. Dessication of the clay layer during a drought would cause shrinkage and possibly cracks in the cover. Any sand in the surface layer could fill the cracks, with a resulting increase in the permeability and probably an increase in the rate of infiltration of water through the wastes.

The swelling properties of clays, especially montmorillonite, are also affected by the chemical environment. Grim (1962) notes that the swelling of montmorillonite can be extremely sensitive to calcium. For example, only 1.1 g/cm² of calcium would be required to displace 50% of the exchangeable ions in a 3-m (10-ft) thick clay layer having a 10% montmorillonite content; this probably would increase the permeability of the clay. Much less calcium would be required to increase the permeability of fractures or of other permeable zones in the clay. It is possible that the clay beneath the current disposal area would be chemically affected by interaction with the wastes. For example, any calcium or organic substances in the waste material, or in the material used to stabilize the wastes, might affect the expandability of the clay minerals. Thus, interaction between the wastes and the clay beneath the disposal area could have an important effect on permeability of the clay layers. The permeability of the clay layers in the cover might be increased if limestone (calcium carbonate) were used for the cobblestones, especially if the clay contained montmorillonite.

To evaluate any possible changes in the clay minerals, it is very important that information (not currently available) be collected and utilized in the design stage regarding site-specific clay mineralogy, flow pathways beneath the pits, concentrations or identity of the organic matter present in the wastes, and leachability of the stabilized wastes.

To ensure long-term integrity of the disposal cell, it is important that the clay liners be designed and emplaced according to sound engineering

practices. Field permeability measurements should be made and used in the design phase to estimate the rate of infiltration through the wastes after they are covered and through the clay beneath the disposal cell. Field permeability measurements might indicate higher permeabilities than laboratory measurements because chemical interactions and laboratory measurements seldom include the effects of fractures and other inhomogeneities.

5.6.1.2 Biotic Effects on Long-Term Integrity of Containment Systems

Biota can affect the long-term integrity of disposal cells, both beneficially and adversely. For cells that have multilayered covers with vegetated soil as the outermost layer, beneficial biotic effects include soil stabilization and erosion control (Section 5.6.1.1); adverse biotic effects include the potential for plant and animal intrusion into the wastes followed by the possible mobilization and dispersal of contamination via physical and biological pathways. Biointrusion, in addition to physical and chemical factors (see Section 5.6.1.1), has contributed to cover integrity problems experienced at most commercial and DOE shallow-land burial sites (Jacobs et al. 1980; Hakonson et al. 1982). Average penetration depths for plant roots and burrowing animals (under optional soil conditions) generally equal or surpass depths to which wastes are placed in shallow-burial disposal sites (Smith 1974; Fitzner et al. 1979; Cline et al. 1982; Foxx et al. 1984a, 1984b).

Root penetration into buried radioactive wastes has been reported for various low-level waste disposal sites (Cline and Uresk 1979; Fitzner et al. 1979; Breedlow et al. 1982; Yamamoto 1982). As a result, waste constituents may be taken up and transported to above-ground or near-surface plant organs (Knight 1983). Waste constituents can then be dispersed either directly to the atmosphere (as in the case of radon) or to food webs via a variety of herbivores (e.g., mammals, reptiles, and insects). Physical dispersal of contaminated plant parts by wind and water can also occur.

Rodents, carnivores, ants, and termites have also been reported to burrow into buried radioactive wastes (Fitzner et al. 1979). Tunneling by animals causes soil pulverization, transfer of materials between layers of the disposal cell structure, and creation of voids. Wastes brought to the surface by burrowing would be subject to accelerated erosion and dispersal in the environment. Therefore, the potential exists for the cover to be reduced after a number of years, rendering the wastes more readily available for transport by physical or biological processes (McKenzie et al. 1982). In addition to burrowing, animals may jeopardize cover integrity by grazing. Grazing can cause a decrease in plant cover, leading to increased erosion.

There are four major alternative cell designs: above-grade (Proposed Action), partial burial (Alternative D), deep trench (Alternatives A and B),

and underground (Alternative C) (see Appendix B). Cell covers for both the above-grade and partial-burial alternatives may eventually be invaded by roots and animals. Initially, the effective rooting zone would be only about 0.6 m (2 ft) (the depth of topsoil), precluding the development of most mature native trees (Spurr and Barnes 1973) and limiting many other deep-rooting plants. Shrubs and trees would germinate and become established in this soil depth, but their growth would slow when the roots encountered the graded clay-to-cobble-sized intrusion barrier. Extensive lateral rooting can be assumed if the intrusion barrier layer were reached, resulting in conditions that could compromise cover integrity such as increased water infiltration and decreased soil bulk density.

These potential impacts would be mitigated by the intrusion barrier, low-permeability soil layer, sand and gravel capillary break layer, clay cap layer, and interlying geotextile liners. These layers would all help to impede root growth and delay penetration into the wastes. The cover could be repaired in areas where root penetration was most serious.

The intrusion barrier, low-permeability soil layer, sand and gravel capillary break layer, and clay cap layer (coupled with geotextile liners between the soil and sand and gravel layer) in the cell cover would also initially deter burrowing animals from intruding into the wastes. However, as root growth modified and disrupted these layers, mammals, ants, and other insects could intrude into the contaminated materials.

Essentially no potential for biointrusion into the wastes is expected for the deep-trench and underground disposal alternatives. Biota would be very unlikely to intrude into more than 6.1 m (20 ft) of clay (even over the long term) for the deep-trench alternative, and animals would be unlikely to intrude into the barrier used to seal the shaft for the underground alternative.

5.6.2 Impacts on Mineral Resources

5.6.2.1 West Chicago Site (Proposed Action)

The West Chicago site lies on the far north side of the Illinois Coal Basin (see Figure 1.1), and no coal deposits are located at or near the site. As much as 14 m (46 ft) of sand and gravel deposits (Units C and E combined) lie near the surface of the Intermediate Site (see Section 4.6.1), and lenses of sand and gravel are also present near the surface in the Disposal Site area. These resources could not be mined if the Proposed Action were implemented. However, sand and gravel deposits are widespread throughout northeastern Illinois (Masters 1978; Lineback 1979; Berg and Kempton 1984), and numerous sand and gravel operations are currently active there (Masters

1978; Samson 1985). Therefore, the loss of a small sand and gravel deposit would have no measurable effect on total resources, materials availability, or the industry in northeastern Illinois.

5.6.2.2 Active Surface Coal Mine (Alternative A)

The operator of the Rapatee Mine is removing all of the No. 5 and No. 6 coals within its permit boundary. No. 6 Coal has been surface mined in the Rapatee Mine area over the past 50 years; therefore, few or no recoverable reserves of that seam would remain in the area after the Rapatee Mine is closed (Smith and Berggren 1963; Treworgy et al. 1978; Ill. State Geol. Surv. 1984a). Blocks of No. 5 Coal will remain in the area (e.g., north of Rt. 116 and north into Knox County) after the Rapatee Mine is closed, but it is highly unlikely that these reserves would justify opening a new mine anytime in the future. The No. 2 Coal is the only other coal seam of economic importance in northern Fulton County. At the Rapatee Mine, the No. 2 Coal is about 61 cm (24 in.) thick, but it is about 80 to 85 m (262 to 279 ft) deep (Smith and Berggren 1963; Treworgy et al. 1984a), a depth too great for profitable surface-mining operations.

No deep-minable coal reserves occur in Fulton County with high or intermediate development potential; about 200 MT (230 tons) of No. 2 Coal in Fulton County has low development potential, but the exact location of this reserve is not specified (Treworgy and Bargh 1982). It is highly unlikely that a coal seam with a thickness of 61 cm (24 in.) would be mined underground.

Overall, implementation of Alternative A should not affect coal resources in the area, mainly because Midland Coal Company is already removing the two most important coal seams (No. 5 and 6) there.

5.6.2.3 Reclaimed Surface Coal Mine (Alternative B)

At the Elm Mine in western Peoria County, the No. 6 Coal has been mined in patches (Ill. State Geol. Surv. 1984b). Therefore, surface-minable reserves of No. 6 Coal remain in the area, particularly on the south side of the Elm and Edwards mines. In the southern third (Sections 25-36) of T9N, R5E, the depth of the No. 6 Coal ranges from 15 to 46 m (50 to 150 ft) (Smith and Berggren 1963), making it easily within reach of surface mining. The No. 6 Coal in this area is from 1.2 to 1.5 m (4 to 5 ft) thick.

The No. 5 Coal at the Alternative B site is approximately 1.2 m (4 ft) thick and 21 m (70 ft) deeper than the No. 6 Coal (Wanless 1957; Smith and Berggren 1963). It is not likely, therefore, that the No. 5 or any other of the deeper coals (i.e., the Houchin Creek No. 4, Colchester No. 2, or Pope Creek Coal seams) would be surface mined at this site. It may be feasible to

surface mine these coals to the north of the site between the Elm Mine and Kickapoo Creek. Along the valley of Kickapoo Creek, the overburden above these lower coals thins significantly. No. 5 Coal reserves to the north and northwest of the Elm Mine are significant and potentially recoverable by surface mining (Treworgy et al. 1978).

None of the coal seams in Peoria County have a high or intermediate potential to be deep mined; large reserves of No. 5 and No. 2 coals have low potential to be deep mined, but no specific locations are given for these reserves (Treworgy and Bargh 1982).

Overall, little potential exists for additional coal mining in the immediate area of the Alternative B site. If any potential exists, it would probably be for surface mining to the north of the Elm Mine, where reserves of the No. 6 Coal seam remain (e.g., Sections 13-18, 20, T9N, R5E) or where the No. 5 Coal lies less than 36 m (120 ft) below the land surface.

No sand or gravel deposits are located in the flat upland area around the Alternative B site.

5.6.2.4 Underground Coal Mine (Alternative C)

The only coal mines (surface or underground) ever to exist in Douglas County are the Murdock and No. 5 underground mines where Herrin No. 6 Coal is being extracted. Additional reserves of No. 6 Coal lie all around these two mines (Treworgy et al. 1984c), with the greatest area and thickness of No. 6 reserves lying to the north and northeast (T16N, R10E; T16N, R11E; and T16N, R14W) in the northeastern corner of Douglas County. Movable reserves of No. 6 Coal are truncated to the west, north, and east of the active mines because of thin overburden near bedrock valleys. Reserves on the south side of the Murdock Mine are limited because the No. 6 Coal seam splits and the lower half of the seam is only about 0.9 m (3 ft) thick. After the reserves in these two underground mines are exhausted, the best reserves under the most advantageous mining conditions would have been mined. It is unlikely that the remaining reserves and less favorable mining conditions would warrant opening another underground mine in this area.

The Springfield No. 5 Coal lies approximately 15 m (50 ft) below the No. 6 Coal and is less than 76 cm (30 in.) thick in the vicinity of the Murdock Mine (Treworgy et al. 1984b). There is little or no potential for underground mining of this seam in the immediate area. The No. 5 Coal thickens slightly to the southwest in T15N, R9E, and is much thicker (1.1-1.4 m) on the far west side of Douglas County in T15N, R7E, and T16N, R7E (Treworgy et al. 1984b). At these locations, there is a low to moderate potential for future underground mining (Treworgy and Bargh 1982).

No other coal seams in Douglas County are thick enough to be mined underground (Treworgy and Bargh 1982). Because the coals are more than 45 m (150 ft) deep almost everywhere in the county, there is also no potential for surface mining (Nance and Treworgy 1981; Treworgy and Bargh 1982).

Surface sand and gravel deposits do not exist over the Murdock and No. 5 mines, but small deposits do exist in the valleys of the Embarras and Brushy Fork rivers. These deposits are not being exploited; in fact, there are no sand and gravel operations in all of Douglas County (Samson 1985).

Many oil and gas wells were drilled in eastern Douglas County, but they were all dry. There has been no active oil or gas exploration or production in this part of the county recently.

Overall, there should not be any adverse impact on mineral resources if Alternative C is implemented, assuming that Ziegler Coal Company removes a large portion of the recoverable No. 6 Coal reserves from eastern Douglas County before the mines cease operation. -

5.6.2.5 Farmland Site (Alternative D)

Pennsylvanian strata, including several coal seams, lie beneath about 36 m (120 ft) of glacial deposits at the Alternative D site. The No. 7 Coal is about 67 m (220 ft) deep, and the No. 6 Coal is about 76 m (250 ft) deep; the Springfield No. 5, Houchin Creek No. 4, Lowell, and Colchester No. 2 Coal members are all more than 100 m (330 ft) deep (Jacobson 1985). At these depths, there is no potential for surface mining of these coals (Smith 1968; Treworgy et al. 1978; Jacobson 1985).

The Alternative D site does not lie in a township containing deep-minable coal resources with high development potential (Treworgy and Bargh 1982). Small quantities of Class II coal reserves (mostly Colchester No. 2 Coal) occur in T30N, R5E, but they are less than 0.9 m (3 ft) thick and have low development potential (Jacobson 1985). Thus, there is very little likelihood that the coal resources near the Alternative D site would ever be developed.

No surface sand or gravel resources or oil and gas deposits are known in the area of the Alternative D site.

5.6.3 Mitigative Measures

5.6.3.1 West Chicago Site (Proposed Action)

No mitigative measures are recommended for alleviating the impact on the sand and gravel deposits at the West Chicago site. To reduce the rate of erosion through the cover layers, materials should be carefully selected. The

clay liners should also be designed and emplaced properly to ensure long-term integrity of the disposal cell. Mitigative measures to reduce the potential for biointrusion through the disposal cell cover could include removal of large, deep-rooted plants; herbicide application to eliminate and prevent regrowth of such plants; maintenance of enclosure fences; trapping and/or poisoning of burrowing animals; insecticide application to control ants and other insects; mowing; and additions to and recompaction of the soil layer. These measures might have to be reapplied periodically to maximize the potential for long-term prevention of biointrusion. The mitigative measures for maintaining disposal cell integrity are also applicable to the Alternative D site. Use of these measures to reduce biointrusion potential would depend upon a final decision for vegetative cover type (i.e., tallgrass prairie or forest), governmental regulations regarding application of pesticides, and so forth.

5.6.3.2 Active Surface Coal Mine (Alternative A)

Small blocks of No. 5 and 6 coals will remain in the permit area after the Rapatee Mine is closed because the coals lie near roads or buildings or are located in areas otherwise inaccessible to mining. Outside the Rapatee permit area, reserves of No. 5 and No. 6 coals exist, but these blocks should not be adversely affected by disposal of the Kerr-McGee wastes. By locating the disposal cell near the center of the mine permit area (e.g., Section 11), the recoverability of coal resources outside of the permit area should not be affected.

5.6.3.3 Reclaimed Surface Coal Mine (Alternative B)

The No. 5 and No. 6 coals that remain in and around the Elm Mine area are potentially accessible by surface-mining operations (i.e., the seams are less than 45 m deep), but it is doubtful whether these coal resources are economically recoverable or will ever be developed. The location of the Alternative B site was selected to minimize the amount of coal resources lost (see Appendix A, Section A.4). Other mitigative measures are unnecessary and economically unfeasible.

5.6.3.4 Underground Coal Mine (Alternative C)

The operator of the Murdock and No. 5 mines is removing as much of the Herrin No. 6 Coal in its permit area as is economically feasible. Blocks of No. 6 Coal (outside the permit area) and No. 5 Coal will remain in eastern Douglas County, but the economic feasibility of recovering these resources is highly doubtful. No other mitigative measures are recommended.

5.6.3.5 Farmland Site (Alternative D)

The coal seams underlying the Alternative D site are too deep for surface mining and are not of significant thickness or value for underground mining. The likelihood of developing these coal resources is very slim. The only mitigation required at the farmland site would be measures to reduce the rate of erosion. These measures are similar to those recommended for the Proposed Action at the West Chicago site.

5.7 WATER RESOURCES

5.7.1 Surface-Water Impacts

5.7.1.1 West Chicago Site

Proposed Action. Surface-water impacts resulting from implementation of on-site disposal (Proposed Action) would be temporary and would be practically eliminated after site reclamation. The primary impacts would include temporary increases in sediment loads and contaminant concentrations (chemicals and radionuclides) in Kress Creek and perhaps in the West Branch DuPage River. These impacts would result from such factors as rainfall-induced surface runoff during on-site demolition, excavation, disposal cell construction, and waste burial. The runoff would be collected in ditches and diverted to detention ponds where the water would be treated, if necessary, and released at a rate controlled by the city of West Chicago (Kerr-McGee 1986--Vol. IX).

Chemical and radionuclide contaminants would also enter surface waters by three other pathways: (1) washout of atmospheric contaminants directly to the surface water, (2) washout of atmospheric contaminants to the land and their subsequent transport by overland flow or groundwater transport to the surface water, and (3) groundwater transport to the surface water of contaminants residing in the ground. These pathways, as well as surface runoff, are expected to result in a minimal impact on surface water because of the good housekeeping and water-control procedures that would be carried out at the West Chicago site (Kerr-McGee 1986--Vol. IX).

After the disposal plan has been fully implemented at the West Chicago site, surface-water contamination from surface runoff and atmospheric washout is unlikely because the disposal cell would be monitored and maintained (see Chapter 7). Surface-water contamination from groundwater transport to surface water is also unlikely because the disposal cell design and groundwater transport media would tend to retard the movement of contaminants in soils (see Section 5.7.2).

Alternatives A-D. Off-site disposal would result in surface-water impacts at the West Chicago site similar to those associated with on-site disposal. Demolition, excavation, and grading would still be required at the West Chicago site. Packaging and loading of trucks for transport of the wastes would take place, but no cell construction activities would occur. As a result, the impacts on surface water are expected to be less than those for the Proposed Action because there would be less disturbance and consequently smaller amounts of contaminants released to surface waters than would result from cell construction activities.

Some increase of contaminant loadings of surface runoff along the transportation routes is expected during the action period because of possible spillage along the route. However, careful loading and washing of the trucks, proper attention to securing the load, and safe driving practices should help to minimize such impacts.

No impacts are expected on surface water at the West Chicago site following completion of the action period because no wastes would remain at the West Chicago site.

5.7.1.2 Active Surface Coal Mine (Alternative A)

Surface-water characteristics at the Alternative A site are described in Section 4.7.1.2. The primary impacts at the site would include temporary increases in sediment loads and in nonradioactive and radioactive contaminants in tributaries of Swegle Creek and Littlers Creek and in water ponds, resulting from rainfall-induced runoff during the disposal operation. The surface-water impacts for Alternative A would be temporary; and, upon proper implementation of the disposal plan, impacts to surface waters are expected to cease.

5.7.1.3 Reclaimed Surface Coal Mine (Alternative B)

Surface-water characteristics at the Alternative B site are described in Section 4.7.1.3. The primary surface-water impacts at the site would include temporary increases in sediment loads and in chemical and radiological contaminants in tributaries of the West Fork of Kickapoo Creek and Clarks Branch and in water ponds, resulting from rainfall-induced runoff during the disposal operation. Draining the lake at the site prior to construction activities would also result in increased amounts of runoff containing soil loadings and radiological and chemical contaminant concentrations characteristic of lakes in abandoned, strip mines. The draining may have to be managed carefully to keep impacts to a minimum. Upon proper implementation of the disposal plan, the impacts to surface waters should cease.

5.7.1.4 Underground Coal Mine (Alternative C)

Surface-water characteristics at the Alternative C site are described in Section 4.7.1.4. During the action period, there might be some impacts on surface water quality from wastewater generated by vehicle washdown and from runoff from piles of wastes stored temporarily at the mine site (see Section 3.5 and Appendix B). This impact would be minimized by treating the water if necessary before releasing it to the environment. After site closure, there should be essentially no impact on surface water quality because the wastes would be stored underground and no pile rising above the original ground level would be present to generate runoff.

5.7.1.5 Farmland Site (Alternative D)

Surface-water characteristics at the Alternative D site are described in Section 4.7.1.5. The primary impacts would include increases in sediment loadings and in nonradioactive and radioactive contaminants in the Vermilion River and perhaps in the West Fork of the Mazon River, principally resulting from rainfall-induced runoff during the disposal operation. The surface-water impacts for this site would be temporary; and, upon proper implementation of the disposal plan, the impacts to surface waters should cease.

5.7.2 Groundwater Impacts

5.7.2.1 Model Descriptions

The model used to analyze groundwater impacts is a modified version of a three-dimensional solute transport model that was developed at Oak Ridge National Laboratory (Yeh 1981). The model solves a generalized transport equation analytically and is applicable only under saturated aquifer conditions. Transport and depletion mechanisms included in the model are advection, dispersion, sorption, and radioactive decay.

For the Proposed Action (on-site disposal) and Alternative D (farmland disposal), the wastes would be placed in the unsaturated (vadose) zone above the groundwater table; hence, the model was modified with a contaminant travel-time method described by Gilbert et al. (1983) so that it can handle saturated-unsaturated conditions. The transport media for the Proposed Action and Alternative D may be illustrated as shown in Figure 5.1. Precipitation falling on the waste field would infiltrate through the wastes and transport contaminants down through the unsaturated zone (D_u) into the saturated (aquifer) zone. In this analysis, the waste field was assumed to be a rectangular block with dimensions L_x , L_y , and L_z . The geometry of the contaminated layer was assumed to remain constant during vertical migration in the unsaturated zone. After the contamination reached the water table, it

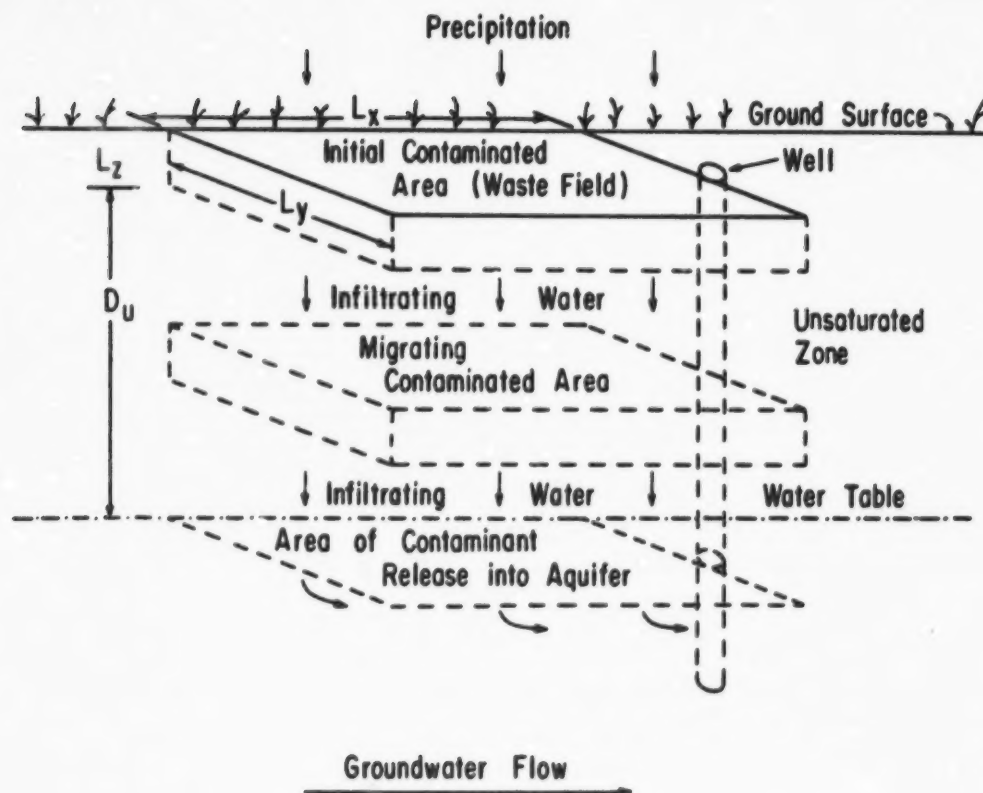


Figure 5.1. Schematic Diagram of Model for Estimating Contaminant Concentrations in Groundwater.

Source: Modified from U.S. Department of Energy (1986).

would spread out and be diluted in the groundwater and would generate a contaminant plume that would move in the downgradient direction.

The source input option of the model was also modified by incorporating a continuous waste-leaching term derived from a first-order leaching model (Baes and Sharp 1983). Other modifications included using total porosity in retardation factor calculations and using three sets of parameters for wastes, unsaturated zone, and saturated zone. All these modifications are discussed in detail in Appendix E, Section E.1.

5.7.2.2 Source Term and Hydrogeological Parameter Values

The quantities of contaminants available for release (i.e., the source term) at the West Chicago and alternative sites were estimated using data presented in Section 2.1.2. The values of various hydrogeological parameters

selected to generate estimates of contaminant concentrations in groundwater are discussed in Appendix E.

5.7.2.3 Radionuclides in Groundwater

Uranium and radium are the radioactive contaminants of importance in estimating potential radiological impacts from groundwater contamination (see Appendix E, Section E.2). The concentrations of thorium in groundwater are expected to be negligible because thorium is strongly bound to soil -- i.e., it has a relatively high distribution coefficient of about 60,000 mL/g (Gilbert et al. 1983). The results of the model calculations are reported here as pCi/L uranium-238 and pCi/L radium-226. For this analysis, natural uranium was considered to be essentially equivalent to total uranium and is higher than the uranium-238 concentration by a factor of 2.05. Radium-228 was not considered because the relatively short half-life (5.8 years) would result in the disappearance of radium-228 by radioactive decay enroute to potable groundwater supplies. Results are reported as "concentration contributions," i.e., the incremental concentrations resulting from leaching of the Kerr-McGee wastes. Background concentrations should be added to the concentration contribution to get the total concentration.

West Chicago Site (Proposed Action). The model simulation indicated that the travel time for radionuclides to move from the bottom of the waste field to the groundwater table (E stratum) at the West Chicago site would be 430 years for uranium-238 and 860 years for radium-226. After the radionuclides reached the groundwater, they would be diluted and move horizontally downgradient toward the site boundary (46 m downgradient from the waste field) (Kerr-McGee 1986--Vol. II). The maximum concentrations in a hypothetical on-site well at the edge of the waste field are predicted to be 0.33 pCi/L for uranium-238, which would occur at 450 years, and 0.11 pCi/L for radium-226, which would occur at 900 years after completion of the disposal cell (see Appendix E). These concentrations are considerably below the NRC limits (10 CFR Part 20) of 30 pCi/L for radium-226 and 40,000 pCi/L for uranium-238, the DOE limits (DOE Order 5480.1A) of 100 pCi/L for radium-226 and 600 pCi/L for uranium-238, and the EPA limit (40 CFR Part 141) of 5 pCi/L for radium-226 and the recommended level of 40 pCi/L for uranium-238 (Cothorn et al. 1983; U.S. Environ. Prot. Agency 1986). The radium-226 concentration is also below the state of Illinois limit (35 Ill. Adm. Code Part 302) of 1 pCi/L (no limit is set for uranium-238).

Active Surface Coal Mine (Alternative A). The waste field would be below the water table for Alternative A (see Section 3.3 and Appendix B). Hence, it was conservatively assumed that the wastes would be saturated after completion of the disposal cell. The leaching of wastes was simulated based on a

first-order ion-exchange model of Baes and Sharp (1983) (see Appendix E). The model simulation indicated that the concentrations of uranium-238 and radium-226 in an on-site well would be 70 pCi/L for uranium-238 and 21 pCi/L for radium-226 at 1,000 years following waste emplacement (see Appendix E).

Abandoned Surface Coal Mine (Alternative B). The disposal cell for Alternative B is a below-grade design (see Section 3.4 and Appendix B), and the waste field would be below the water table. Hence, it was conservatively assumed that wastes would be saturated after completion of the disposal cell. The model simulation indicated that the concentrations of uranium-238 and radium-226 in an on-site well would be 15 pCi/L for uranium-238 and 2.5 pCi/L for radium-226 at 1,000 years after completion of the disposal cell (see Appendix E).

Underground Coal Mine (Alternative C). For Alternative C, the wastes would be buried approximately 76 m (260 ft) below the ground surface. Hence, it was conservatively assumed that the wastes would be saturated after completion of the disposal cell. The model simulation indicated that the concentrations of uranium-238 and radium-226 in an on-site well would be 3.6 and 0.72 pCi/L, respectively, at 1,000 years after completion of the disposal cell (see Appendix E).

Farmland Site (Alternative D). The cell design for Alternative D is partial burial on farmland, and the waste field would be situated right above the water table (see Section 3.6 and Appendix B). Hence, the waste field was assumed to be partially saturated, with zero unsaturated zone depth (see Appendix E). The model simulation indicated that the concentrations of uranium-238 and radium-226 in an on-site well would be 83 and 20 pCi/L, respectively, at 1,000 years after completion of the disposal cell.

5.7.2.4 Chemicals in Groundwater

Concentrations of chemical species in the groundwater were calculated using the same model as was used for the radiological species (Appendix E). The input parameters were the same for the chemical species as the radiological species, except the distribution coefficients (K_d values) and source term concentrations are different for each chemical species. Use of the limited available data to generate values for these parameters is discussed in Appendix E.

Model calculations were made in order to predict peak concentration contributions of chemical species that would occur for all alternatives within 1,000 years following site closure at the downgradient edge of the waste pile and at various downgradient points. The values represent concentration contributions to the groundwater from leaching of the waste pile and do not

include background values. The values are also maxima of all the values along the pile edge or downgradient from the pile edge and apply to the uppermost aquifer. Detailed results are given in Appendix E.

West Chicago Site (Proposed Action). For on-site disposal (Proposed Action), model calculations predict that peak concentrations at the downgradient edge of the waste pile for all chemical species considered would be below the EPA groundwater protection standards and the Illinois general use water quality standards. Predicted peak groundwater concentration contributions of lead and cyanide are 1.4 $\mu\text{g/L}$ at 890 years and 3.3 $\mu\text{g/L}$ at 1.6 years, respectively, after site closure; these are 1.4% and 13% of the Illinois general use water quality standards of 100 $\mu\text{g/L}$ and 25 $\mu\text{g/L}$ (Table 2.9); the lead concentration is 3% of the EPA standard of 50 $\mu\text{g/L}$ (Table 2.8). Predicted peak concentrations of all other chemical species considered are less than 1% of the EPA groundwater protection standards and the Illinois general use water quality standards.

Based on these results, it is predicted that disposal of the wastes at the West Chicago site would result in minimal chemical impact on the groundwater at the site for all chemical species for which model calculations were carried out. (Minimal chemical impact means that peak concentrations at the site boundary in the 1,000-year period would be appreciably less [less than 15%] than the Illinois general use water quality standards and the EPA groundwater protection standards.) This conclusion is considered to be reliable because the model assumptions used tend to be conservative.

Other Disposal Sites (Alternatives A-D). For Alternatives A-D, model calculations predict that within the 1,000-year period, peak concentration contributions at the downgradient edge of the waste pile would be above the relevant EPA or Illinois water protection standards for several chemical parameters. These are cadmium, copper, lead, mercury, and cyanide for Alternative A; cadmium, copper, lead, and cyanide for Alternative B; cyanide for Alternative C; and arsenic, cadmium, copper, lead, and cyanide for Alternative D. The peak concentration contributions within the 1,000-year period, the times of occurrence of the peak concentration contributions, and the groundwater standards are given in Table 5.6. More details are given in Appendix E.

For most parameters and alternatives, the peak concentration contributions would exceed the relevant standards by small factors, less than 2 (Table 5.6). The exceptions are copper for Alternatives A and D, for which peak concentration contributions would exceed the Illinois general use standard of 20 $\mu\text{g/L}$ by factors of 3.0 and 3.2, respectively; and lead for Alternatives A and D, for which peak concentration contributions would exceed the EPA groundwater limit of 50 $\mu\text{g/L}$ by factors of 8 and 4, respectively. The

Table 5.6. Predicted Peak Concentration Contributions, Times of Occurrence, and Water Protection Standards for Some Chemical Parameters^a

Chemical Parameters	Peak Concentrations (µg/L)				Time of Occurrence (yr)				Standards (µg/L)	
	Alt. A	Alt. B	Alt. C	Alt. D	Alt. A	Alt. B	Alt. C	Alt. D	EPA ^b	Illinois ^c
Arsenic	< ^d	<	<	53	- ^e	-	-	600	50	1,000
Cadmium	14	14	<	19	35	300	-	600	10	50
Copper	59	36	<	64	260	1,000	-	1,000	-	20
Lead	400	53	<	200	1,000	1,000	-	1,000	50	100
Mercury	0.61	<	<	<	1,000	-	-	-	2	0.5
Cyanide	550	560	220	980	2.4	21	53	16	-	25

^a Source: Appendix E, Table E.7. Values are given only for those parameters for which predicted peak concentrations exceed relevant water standards. Peak values are those within the 1,000-year period following site closure and do not include background contributions.

^b Groundwater protection standards (see Table 2.8).

^c General use water standards (see Table 2.9).

^d Denotes peak concentration contributions that are below the relevant water protection standards.

^e See Table E.7.

other exception is cyanide for Alternatives A-D, for which peak concentration contributions would exceed the Illinois general use standard of 25 $\mu\text{g/L}$ by factors ranging from 8.8 for Alternative C to 39 for Alternative D.

These results show that disposal of the Kerr-McGee wastes at one of the alternative sites would have some chemical impact on groundwater quality. With regard to the number of chemical parameters for which peak concentrations would exceed the relevant standards, the chemical impacts would be greatest for Alternatives A and D, less for Alternative B, and least for Alternative C. This conclusion is based on conservative estimates of input parameters for the sites. These estimates were used because site-specific data were not available. More details are given in Appendix E.

5.8 ECOLOGY

5.8.1 Terrestrial Impacts

5.8.1.1 West Chicago Site (Proposed Action)

Implementation of any of the waste-disposal alternatives would affect terrestrial biota at the West Chicago site on a short- to long-term basis. The biota would be affected primarily by habitat loss caused by construction activities related to waste removal, waste handling, waste disposal (if on-site disposal were chosen), and site renovation. Although habitat loss is a major cause of decline in wildlife populations (Forsythe and Gard 1980; Fredrickson 1980), the destruction of old-field vegetation at the West Chicago site would not be significant because the plant species present are not unique or restricted in distribution and they readily repopulate disturbed areas.

Destruction of habitat would displace birds into unaffected habitats where they might be subjected to greater intraspecific or interspecific competition for food and nesting resources. If a habitat was at its carrying capacity for a particular species, then that habitat would not support additional individuals contributed from such displacement. This could be the case at the West Chicago site because of the limited amount and diversity of wildlife habitat present in the surrounding developed residential and commercial area. However, the migratory nature of many of the species found at the site (e.g., waterfowl) and the abundance of residential species (e.g., pigeons and sparrows) would result either in the relocation of the birds or in no noticeable impact on the species' population, even if individuals could not be supported in adjacent areas.

Small- to medium-sized mammals and herpetofauna would also be displaced or, more than likely, destroyed by the proposed activities. Species that are more adaptable to the presence of humans, such as skunks and raccoons, might

search construction areas at night for edible debris left by workers. A rodent elimination plan has been established for all buildings on the Factory and Disposal sites; however, most buildings have already been demolished. Stabilization of the disposal area and removal of organic substances would eliminate or greatly reduce the possibility of incorporating contaminants into the food chain, thereby reducing the potential for adverse effects on other wildlife and man.

Fauna inhabiting areas adjacent to the waste-handling operations would probably be disturbed if they were within auditory or visual range of the activities. If these animals were to leave or avoid such areas, areas not physically disturbed by waste-handling activities would also be affected. Animals remaining in the area might have their feeding or reproductive activities affected. Heavy machinery (the anticipated source of most noise) produces just under 90 dB at 16 m (52 ft), with the noise intensity decreasing at 6 dB per doubling of distance (U.S. Environ. Prot. Agency 1974). Values between 50 and 90 dB may cause annoyance (Cheremisinoff and Cheremisinoff 1977). Because trees, buildings, and other barriers cause the sound waves to lose energy, the area of annoyance would most likely be within a relatively short distance of site activities. The consequences to wildlife from noise or visual distractions are not well documented, so it is difficult to predict how much impact these factors would have on the local fauna (Soholt and Bynoe 1982). However, the impacts should be small because fauna in the vicinity are already exposed to disturbances associated with wildlife habitats located in an urban setting.

Dust generated by construction traffic and equipment operations would be deposited on adjacent vegetation, which could affect photosynthesis and plant growth, as well as make the vegetation less palatable to wildlife (Dvorak et al. 1977). However, these impacts should be negligible because of the relatively low abundance of wildlife in the area combined with mitigative measures to control dust.

Site maintenance and monitoring would continue past site cleanup and closure of the disposal area. There are two alternatives for vegetational development on the waste cover (Kerr-McGee 1986--Vol. XI): (1) establishing and maintaining a tallgrass prairie or (2) establishing a tallgrass prairie and allowing it to undergo natural succession to forest.

A tallgrass prairie can be maintained by either burning or mowing once every two or three years. Although both methods are effective in maintaining prairie conditions, mowing would be environmentally preferable in the urban environment of West Chicago. Supplemental maintenance would also be employed to remove woody vegetation (e.g., by use of herbicides) and to repair the cover (e.g., where vegetation did not adequately develop). Such maintenance

activities would limit wildlife diversity and use of the area. The number of early successional plant species occurring on the area would largely depend on the amount of landscaping and vegetative control conducted during this period of site control. Early successional plant species would include grasses and forbs (those listed in Appendix D, Table D.5, as occurring in fields, roadsides, and waste grounds) and low-growing trees and shrubs.

Animals would also repopulate the site. Many bird and mammal species typical of suburban/urban areas would be expected to readily inhabit and utilize the site. Due to the elimination of almost all on-site aquatic habitats and the creation of just a small detention basin, only a few herpetofauna species, such as the eastern garter snake and American toad, are expected to become reestablished at the site following restoration.

Detrimental impacts on terrestrial biota from maintaining prairie conditions have generally been reported for smaller wildlife species such as small mammals, snakes, and ground-nesting birds (Seigel 1986). However, the effects of such maintenance activities depend upon several factors, including seasonal timing of maintenance, shelter available to the wildlife, and species present. Thus, mitigative measures could be taken at the West Chicago site to minimize impacts to wildlife (Section 5.8.3).

If the second alternative for vegetative development on the cover was implemented (i.e., natural succession to forest), only corrective maintenance would be required to ensure that cover integrity was not being jeopardized during the natural succession process. A chronology of vegetational succession on the cover is provided in Appendix D, Table D.8.

Animal species that could inhabit the cover under the second alternative include those currently associated with the West Chicago site (see Section 4.8.1.1) and those associated with wooded habitats. These include the more common and widespread species listed in Appendix D, Tables D.1 through D.3, that are associated with wooded edges, woodlots, thickets, and other habitat types containing wooded vegetation. However, the comparatively small size of the West Chicago site, combined with its urban location, would prevent development of a diverse wildlife assemblage as found in a large forested tract in rural settings.

No impacts to the Indiana bat are anticipated for the Proposed Action because the bat's habitat does not correspond to that found at the West Chicago site. Additionally, no impacts to state-listed plant species are expected due to their unlikely occurrence at the West Chicago site.

If the Kerr-McGee wastes are disposed of at one of the alternative sites, the West Chicago site would be released for other use. The use made of the

land -- e.g., recreational (park), industrial, or residential -- would govern the biotic composition that would develop on the site.

5.8.1.2 Active Surface Coal Mine (Alternative A)

Impacts to terrestrial habitats and biota at the active surface coal mine site would be similar to those described for the West Chicago site (Section 5.8.1.1). However, the area to be disturbed by site preparation and waste storage would be somewhat less (Appendix B, Table B.3). Additionally, compared with the West Chicago site, which is affected by urban encroachment, fauna displaced from the active surface coal mine site would have greater potential to successfully relocate to other habitats capable of supporting them. Following site renovation, species adapted to pasture and old-field habitats could readily reinvade the site. Habitat and species composition comparable with that currently existing on older spoil piles and/or reclaimed portions of the site (except for mature trees that may be present) could become reestablished within a few years following waste disposal, but the rate would depend on the type of maintenance activities conducted at the site.

If the wastes were placed within an unreclaimed, recently mined area of the site that was devoid of vegetation and wildlife, the only impacts would be a delayed establishment of biota relative to the extra time needed for waste-disposal activities prior to site renovation. Site maintenance would also affect the rate at which biotic development would occur on the site.

No impacts to the Indiana bat are expected because its habitat does not coincide with that found at the active surface coal mine site. However, the state-listed American bittern and upland sandpiper could potentially be affected, and reconnaissance surveys would have to be conducted prior to any waste-disposal activities. If these species were encountered, the state would be contacted to determine necessary procedures for minimizing potential impacts. Impacts to state-listed plant species that occur, or are historically known, from Fulton County are not expected because their habitats do not coincide with habitats existing at the active surface coal mine site.

5.8.1.3 Reclaimed Surface Coal Mine (Alternative B)

Impacts associated with waste disposal at the reclaimed surface coal mine site would essentially be similar to those at the active surface coal mine site (Section 5.8.1.2). No impacts to the Indiana bat would be expected, but a few state-listed plant species could potentially occur at the site (see Section 4.8.3.3). A reconnaissance survey for the plant species would have to be conducted prior to waste-disposal activities at the site. If any state-listed plant species were found, the state would be contacted to determine necessary procedures for minimizing potential impacts.

5.8.1.4 Underground Coal Mine (Alternative C)

Although habitats associated with the underground coal mine site are somewhat comparable to other alternative sites, fewer impacts to terrestrial biota would be expected because the wastes would be emplaced within the mine where little or no wildlife occur and the areas around the mine entrance would already be disturbed from coal handling and storage operations. Impacts to the state-listed ginseng are not expected because waste-disposal activities would be conducted within the immediate area of the mine entrance where the plant is not expected to occur.

5.8.1.5 Farmland (Alternative D)

Impacts associated with waste disposal at the farmland site would be somewhat similar to those discussed for the West Chicago and active surface coal mine sites (see Sections 5.8.1.1 and 5.8.1.2). A few of the federally and state-listed animal species from adjacent LaSalle County could potentially occur at the site. Prior to any site activities, a reconnaissance survey would have to be conducted. If any listed species were identified, the state and the U.S. Fish and Wildlife Service (if the Indiana bat were observed) would be contacted concerning necessary procedures for minimizing potential impacts. No extant populations of state-listed plant species are known from Livingston County; thus, no impacts are expected.

5.8.2 Aquatic

5.8.2.1 West Chicago Site (Proposed Action)

Removal of on-site ponds due to drainage, burial, and regrading would eliminate aquatic habitats and associated biota. The species contained in the aquatic habitats are not unique and have widespread distributions; therefore, adverse environmental impacts related to their elimination would be localized and insignificant. The minor amount of aquatic habitat created by the small permanent detention ponds would develop a biotic community similar to that occurring in the smaller, existing on-site ponds.

During earth-moving activities, siltation of Kress Creek could occur by sheet water runoff during precipitation events carrying soil into the creek (Argonne Natl. Lab. 1978). Potential impacts associated with suspended and settled solids include loss of food supplies, destruction of spawning habitat, scouring of algae and benthic invertebrates from the substrate, reduced primary productivity, clogging of gills, reduced growth rate and/or resistance to disease, alterations in movements and migrations, changes in species composition to less desirable species, and creation of oxygen demands and/or production of toxic compounds resulting from decomposition of organic debris

carried to the bottom as suspended solids settle (European Inland Fisheries Advisory Commission 1965; McKee and Wolf 1971). Factors influencing the severity of impacts include degree of runoff and methods of control, precipitation events (number and intensity), seasonal variations, stream and site drainage flows, and dilution volume available. Negative impacts associated with siltation should be temporary (during earth-moving and regrading activities) and reversible. Additionally, suspended solids discharged to the creek can be minimized with proper earth-moving and erosion-control practices (see Sections 5.6.1 and 5.6.3).

In theory, when decommissioning is finished, containment of the wastes should have a beneficial effect on the biota of Kress Creek. In reality, it is doubtful that the Proposed Action would have any measurable impact because other perturbations -- e.g., wastewater outfalls and nonpoint pollution from other sources -- have an overriding influence on the water quality and biota of the creek.

No endangered or threatened species occur in any of the water bodies that would be affected by site activities.

Aquatic impacts at the West Chicago site associated with waste disposal at an alternative site would, for all practical purposes, be the same as for on-site disposal. Impacts related to on-site disposal would still occur as a result of waste removal and handling, preparation of the wastes for transport, and site renovation.

5.8.2.2 Active Surface Coal Mine (Alternative A)

Generally, impacts to aquatic and wetland habitats that would occur at the West Chicago site would also be expected at the active surface coal mine site -- e.g., elimination of on-site habitats (if any), creation of a small detention pond, and siltation of habitats receiving site drainage. If a recently mined area was selected for waste disposal, any aquatic system in that vicinity would probably already have been impacted from mining operations.

Potential impacts on receiving streams near the active surface coal mine site would depend on (1) the size and permanence of the stream, (2) current stresses and water quality conditions of the stream, (3) distance (and interlying topography) between disposal site activities and the stream, and (4) erosion potential of the disposal site. These factors would similarly affect the potential for impacts on lentic water bodies (e.g., strip mine lakes, ponds, wetlands) at or near the disposal site area.

Waste-disposal activities would mostly be located some distance from larger streams, and few or no impacts related to siltation would be expected. Smaller tributary streams might be located close enough to the waste-disposal activities to be either physically destroyed or impacted by siltation. It is not anticipated that a diverse fish assemblage occurs in such streams. However, small tributary streams often contain a diverse assemblage of invertebrates as well as amphibian species. Nevertheless, overall impacts would be minimal because (1) such habitats are numerous within the area, (2) impacts would be localized, and (3) most waste-disposal activities would not occur in the wetter areas of the active surface coal mine site.

No significant impacts to aquatic habitats related to waste containment at the active surface coal mine site are expected. Site maintenance activities would be confined to the immediate disposal site and would include measures for controlling erosion and runoff to ensure disposal cell integrity.

No endangered or threatened species occur in any water bodies that would be affected by site activities.

5.8.2.3 Reclaimed Surface Coal Mine (Alternative B)

Impacts associated with waste disposal at the reclaimed surface coal mine site would be quite similar to those described for waste disposal within revegetated or older spoil pile areas of the active surface coal mine site (Section 5.8.2.2). An exception is that a strip mine lake occupying a portion of the site would be drained. For all practical purposes, this would result in the elimination of aquatic biota occurring in the lake (e.g., fish, invertebrates, macrophytes). However, the strip mine lake is one of many similar man-made aquatic habitats in the area. Thus, loss of biota associated with the lake is not considered ecologically significant (e.g., of importance in sustaining the populations of any species occurring in the area). Potential off-site impacts would also be similar.

No endangered or threatened species occur in any of the water bodies that would be affected by site activities.

5.8.2.4 Underground Coal Mine (Alternative C)

Aquatic habitats in the vicinity of the underground coal mine site are similar to those occurring at the surface coal mine sites (see Sections 4.8.2.2 and 4.8.3.2), except for the lack of strip mine lakes. Fewer impacts would potentially be associated with disposal in the underground coal mine because (1) the wastes would be emplaced within the mine panels, thereby precluding surface area disturbance, and (2) the areas for ancillary facilities and initial waste unloading would be in an area already disturbed

from coal handling and storage operations. If aquatic habitats existed in the immediate vicinity of the mine, they would have been previously impacted from mining-related activities.

No endangered or threatened species occur in any of the water bodies that would be affected by site activities.

5.8.2.5 Farmland (Alternative D)

Potential aquatic impacts at the farmland site would primarily occur from direct elimination of habitat. The unused lands of such a site are usually the areas where small ponds, drainageways, and wetlands occur. Impacts resulting from the elimination of such habitats would be similar to those described for the West Chicago site and active surface coal mine site (see Sections 5.8.2.1 and 5.8.2.2). Some potential for siltation would exist if the wastes were deposited into or close to tributary streams. Otherwise, the potential for siltation to streams would be minimal because the land in the farmland area is relatively flat. This fact, coupled with mitigative measures to control erosion (see Sections 5.6.1 and 5.6.3), would minimize the potential for uncontrolled off-site releases of sediment. A small detention pond would be constructed that would develop a biotic community similar to that of typical farm ponds in the area.

No endangered or threatened species occur in any of the water bodies that would be affected by site activities.

5.8.3 Mitigative Measures

Many of the mitigative measures suggested for minimizing impacts to land, soil, and water resources (Sections 5.4.2, 5.6.3, and 5.7.1) would also effectively reduce potential impacts to ecological resources. The following mitigative measures, aimed specifically at protecting terrestrial and aquatic biota and their habitats, are generally applicable to all alternative sites.

5.8.3.1 Terrestrial

Existing access and cleared areas should be used to the fullest extent possible. If new access is needed, it should follow the natural contour of the land, wherever possible, to avoid excessive cutting and filling. All access should be maintained to minimize erosion due to construction traffic. Following disposal activities, access roads, construction laydown and staging areas, and other locations not needed for site maintenance should be returned to their original contours and revegetated.

Several measures should be taken during construction to limit unavoidable impacts to the immediate disposal site area. The natural topography should be maintained as much as possible, and disturbances to unstable areas should be minimized. Construction vehicles and equipment should not be operated when a combination of unfavorable weather and site conditions could result in unacceptable wind or water erosion. Excess excavated materials should be removed to a suitable disposal site. Fuels, chemicals, oils, grease, solid wastes, and other materials should be stored and handled in a manner that would prevent spills. During site-construction and waste-disposal activities, temporary fences, gates, cattle guards, and so forth should be installed (as necessary) to minimize disturbance to livestock or wildlife (e.g., deer). Also, a corridor should be maintained during construction to allow wildlife to escape to surrounding, unaffected areas.

Several measures are highly recommended during construction and site renovation to maximize the potential for successful revegetation. During site preparation, topsoil should be segregated for subsequent use, and the topsoil storage piles should be covered and/or planted to reduce the potential for erosion. Following construction and waste emplacement, damaged areas should be repaired by reestablishment of original contours, filling in of ruts, and reseedling and mulching of the disposal cell area. Plants with fibrous roots are preferred to prevent the establishment of species with taproots that generally produce deeper rooting systems (Foxy et al. 1984b). Vegetative management should include (1) deterring the propagation of weeds and dumping of trash to help avoid the attraction of undesirable scavengers and burrowing animals to the site and (2) confining controlled burning or mowing of vegetation to the disposal cell and the immediate area surrounding it. Mowing or burning should be scheduled to coincide with periods of wildlife inactivity (e.g., according to seasonal or diurnal habits); and if controlled burning is used, a buffer strip should be maintained to uncontrolled areas in order to allow an escape route for wildlife.

5.8.3.2 Aquatic

Several of the mitigative measures that would protect terrestrial systems, primarily those designed to control erosion, would also effectively protect aquatic and wetland habitats. For example, major disposal and related construction activities should not be conducted during periods of heavy precipitation unless they can be done with minimal potential for runoff. Also, the disposal site and access routes should be located to avoid areas of unstable soils, steep slopes, streams, and wetlands whenever possible. Overland travel near aquatic and wetland areas should be limited to minimize potential soil erosion and sediment transport.

Where feasible, the disposal cell should be designed and constructed to achieve minimal interference with local drainage patterns. Impacts to aquatic systems can be minimized by proper construction, operation, and monitoring of a site runoff diversion system, including the use of runoff detention pond(s). Excavated materials should not be intentionally placed on aquatic or wetland habitats. Vegetated buffers should be left along aquatic and wetland habitats to stabilize the soil and trap sediments -- thus minimizing surface runoff, erosion, and other adverse impacts to water quality. Refueling of construction vehicles, storage of construction materials, disposal of waste materials, and any other handling of potentially contaminating materials should be especially prohibited near aquatic and wetland habitats.

5.9 RADIOLOGICAL IMPACTS

The radioactive wastes at the West Chicago site consist of ore residues, sediments, and other contaminated materials. The total volume of the Kerr-McGee wastes is estimated to be 281,600 m³ (9,943,000 ft³), including materials from the Factory Site, Intermediate Site, Disposal Site, residential areas, and Sanitary Treatment Plant. Most of the wastes are located at the Factory Site (50%) and the Disposal Site (30%) (see Table 2.2).

The alternatives for managing the wastes include on-site disposal (Proposed Action) and off-site disposal (Alternatives A through D). The wastes would be moved from their current locations for the Proposed Action and all alternatives (A-D), resulting in similar radiological conditions and impacts to the West Chicago environment in the near term from implementation of any of the alternatives.

The major source of radiation doses to the general public would result from atmospheric transport of radioactivity during waste handling and from transportation. Several nearby locations were selected for analysis of potential maximally exposed individuals (Table 5.7).

Detailed information and specific waste-disposal plans for each alternative disposal site are presented in Chapter 3. All alternative sites were selected in terms of population, land use, hydrology, geology, accessibility, and transportation distance from West Chicago. The Kerr-McGee wastes are assumed to be transported damp so that the material can be deposited at each disposal site with minimal dusting. Also, because of the remote locations of the alternative disposal sites, the radiological impacts from waste burial activities at these sites are expected to be less than those associated with excavating and loading the wastes at West Chicago. In the long term, radiological impacts to the general public would be expected to be less from off-site disposal than on-site disposal because of the more remote locations of the off-site disposal alternatives.

Table 5.7. Hypothetical Nearby Individuals at the Potential Disposal Sites

Site	Distance (km)	Direction
West Chicago site	0.23	NE
Active surface coal mine	1.0	W
Reclaimed surface coal mine	2.4	W
Underground coal mine	2.8	W
Farmland site	8.0 ^a	SW ^b

^a Due to the sparse population density around the farmland site, a distance of 8 km was assumed for a nearby individual.

^b The southwest direction was selected because of prevailing meteorological conditions.

The dose calculations in this analysis are based on:

- The Environmental Report (revised to July 24, 1980) and the Engineering Report (April 1986) prepared by Kerr-McGee and the Final Environmental Statement prepared by NRC,
- Estimates of expected effluents from the site based on reports of the U.S. Environmental Protection Agency (1977) and the U.S. Nuclear Regulatory Commission (1980a),
- Major exposure pathways from airborne-released radionuclides, i.e., inhalation and external radiation,
- Site meteorological characteristics based on O'Hare Airport (1970-1974), Rantoul (1970-1974), and Peoria (1963-1967) data (see Section 4.2 and Figures 4.7-4.9),
- A Gaussian plume dispersion model (MILDOS) designed to predict ground-level air concentrations resulting from continuous release of uranium-238 or thorium-232 and their decay products from multiple-area sources (modified to include ground deposition, resuspension, and radioactive decay),
- Population distributions for the various alternative sites (see Section 4.3), and

- Radiation dose conversion factors based on recommendations of the International Commission on Radiological Protection (1977, 1979, 1981).

5.9.1 Doses to the General Public

5.9.1.1 Action Period

During the action period, radiological impacts to members of the general public would occur (1) at West Chicago or the alternative disposal site and (2) along transportation routes (for off-site alternatives). The radionuclides in the Kerr-McGee wastes consist primarily of radionuclides contained in two naturally occurring decay series, uranium-238 and thorium-232 (Table 5.8). The highest concentrations of radioactivity are in pond sediments, the sludge pile, and ore residues at the Disposal Site (see Table 2.3). The average concentrations of the radionuclides are given in Table 5.9.

West Chicago and Alternative Disposal Sites. Radon-220 and radon-222 gases and contaminated particulates would be released to the atmosphere as a result of excavation, transfer, and reburial activities; gas diffusion; and wind erosion. At the West Chicago site, radioactive dust emissions are expected to be caused mainly by earth-moving operations associated with relocation of the Kerr-McGee wastes. For off-site disposal, the wastes would be loaded onto either trucks or railroad cars, and emissions associated with either transport mode are expected to be similar. Sludge would be loaded in a wet condition, in which case dust emissions would be similar to those for on-site disposal.

Table 5.8. List of Major Radionuclides in the Uranium-238 and Thorium-232 Decay Series^a

Nuclide	Half-Life	Nuclide	Half-Life
U-238	4.5×10^9 yr	Th-232	1.4×10^{10} yr
↓		↓	
U-234	2.5×10^5 yr	Ra-228	6.7 yr
↓		↓	
Th-230	8.0×10^4 yr	Th-228	1.9 yr
↓		↓	
Ra-226	1602 yr	Ra-224	3.6 d
↓		↓	
Rn-222	3.8 d	Rn-220	55 s
↓		↓	
Po-210	138 d	Pb-212	10.6 h
		↓	
		Bi-212	60.6 min

^a Some radionuclides have been omitted for clarity.

Table 5.9. Concentrations of Major Radionuclides
in the Kerr-McGee Wastes

Source of Material	Average Radionuclide Concentration ^a (pCi/g)				
	Uranium- 238	Thorium- 232	Thorium- 230	Radium- 228	Radium- 226
Factory Site	110	170 ^b	19	170	17
Disposal Site	50	900	110	1,900	290
Others	7.3	44	5.4	51	3.3

^a For the purposes of calculation, uranium-238 represents uranium-238, protactinium-234, and uranium-234 (in secular equilibrium); radium-226 represents radium-226 and the remaining decay products in the uranium-238 decay series; and radium-228 represents all subsequent radioactive members in the thorium-232 decay series.

^b Because thorium-232 data were not available, the concentration of thorium-232 was assumed to be equal to that of radium-228.

The release rate for particulates during the action period was estimated to be 0.2 kg/1,000 kg based upon information for open storage operations (U.S. Environ. Prot. Agency 1977). This release rate was multiplied by a weather correction factor to account for local precipitation and evaporation rate, which ranges from 0.96 to 1.1 for various areas in Illinois. Use of water sprays has been shown to achieve a 50% reduction in fugitive dust generation with a twice-per-day watering schedule (PEDCo-Environ. Spec. 1973). Watering would be carried out more than twice per day, if necessary, to minimize dusting. The amount of fugitive dust generated during these actions would probably be lower than the estimates given here.

The amount of radioactivity released during remedial actions was estimated using the concentration of radioactivity in the various sources (Table 5.9), the amount of material in each of the sources (Table 2.2), and the emission factors described above. These results are presented in Table 5.10. To estimate radon gas emissions during waste relocation, it was assumed that 20% of the radon-222 and 10% of the radon-220 then present in the wastes would be released (Megumi and Mamuro 1974; Argonne Natl. Lab. 1982). The radon was assumed to be in equilibrium with its radium parent in the wastes and released in puffs after relocation for burial.

The estimated radiation doses via atmospheric transport to the general public and potential maximally exposed individuals during the action period are summarized in Table 5.11. The estimated dose from airborne releases to

Table 5.10. Radioactive Emissions during Remedial Actions^a

Alternative	Weather Correction Factor ^b	Particulate Emissions (Ci)		
		Uranium-238	Thorium-232	Thorium-230
Proposed Action	1.1	4.7×10^{-3}	1.8×10^{-2}	2.1×10^{-3}
A	1.0	4.5×10^{-3}	1.7×10^{-2}	2.0×10^{-3}
B	1.0	4.5×10^{-3}	1.7×10^{-2}	2.0×10^{-3}
C	0.96	4.4×10^{-3}	1.7×10^{-2}	2.0×10^{-3}
D	1.1	4.7×10^{-3}	1.8×10^{-2}	2.1×10^{-3}

Alternative	Particulate Emissions (Ci)		Gas Emissions (Ci)	
	Radium-228	Radium-226	Radon-222	Radon-220
Proposed Action	3.0×10^{-2}	4.4×10^{-3}	12	40
A	2.9×10^{-2}	4.2×10^{-3}	12	40
B	2.9×10^{-2}	4.2×10^{-3}	12	40
C	2.9×10^{-2}	4.2×10^{-3}	12	40
D	3.0×10^{-2}	4.4×10^{-3}	12	40

^a Radioactive emissions for off-site disposal (Alternatives A, B, C, and D) involve the emissions resulting from the cleanup work at the West Chicago site and the releases from waste disposal at the alternative disposal sites.

^b The weather correction factor accounts for the effects of precipitation and evapotranspiration.

the general public from on-site disposal (Proposed Action) is 36 person-rem. The estimated doses for the off-site disposal alternatives would all be comparable, about 26 to 27 person-rem over the action period.

Because of the rural locations of the off-site disposal sites, most of the radiation doses from disposal of the Kerr-McGee wastes would be received by the general public in the vicinity of the West Chicago site. The doses to the population around any of the alternative sites from waste disposal would be about two orders of magnitude less than the population doses at the West Chicago site from cleanup actions. All of these doses would be only a very small fraction of the dose received by the same population from background radiation.

Table 5.11. Estimated Doses to the General Public from Waste-Handling Activities^a

Alternative	Site	Effective Dose Equivalent to General Public (person-rem)	Dose to Maximally Exposed Individual ^b (mrem)			
			Effective Dose Equivalent	Bone	Lung	Bronchial Epithelium
Proposed Action	West Chicago site	36	40	590	290	21
A	West Chicago site and active surface coal mine	26 ^C	20	320	140	9.8
B	West Chicago site and reclaimed surface coal mine	26 ^C	20	320	140	9.8
C	West Chicago site and underground coal mine	26 ^C	20	320	140	9.8
D	West Chicago and farmland site	27 ^C	20	320	140	9.8

^a The 1980 census data were used for the population distribution within 80 km (50 mi) of the sites under consideration. All values are given to two significant figures.

^b For every alternative, the maximally exposed individual was assumed to be located 0.23 km (0.14 mi) northeast of the center of the West Chicago disposal area.

^c More than 95% of the population dose is estimated to be received by the general public surrounding the West Chicago site as a result of cleanup activities for the Kerr-McGee wastes.

The effective dose equivalent to the maximally exposed individual for each alternative during the entire action period ranges from a low of 20 (for off-site disposal alternatives) to a high of 40 mrem (for on-site disposal). The maximally exposed individual for all alternatives is assumed to be located 0.23 km (0.14 mi) northeast of the center of the disposal area on the West Chicago site.

Along Transportation Routes. Under Alternatives A through D, the wastes would be transported off-site. Under Alternative A, the wastes would be transported by truck to an active surface coal mine in Fulton County, Illinois, 290 km (180 mi) from West Chicago, Illinois (see Figure 5.2). Under Alternative B, the wastes would be transported by truck to a reclaimed surface coal mine in Peoria County, Illinois, 274 km (170 mi) away. Under Alternative C, the wastes would be transported by truck to an underground coal mine in Douglas County, Illinois, 265 km (165 mi) away. Under Alternative D, the wastes would be transported by truck to a farmland located in Livingston County, Illinois, about 129 km (80 mi) from the West Chicago site.

According to U.S. Department of Transportation (DOT) regulations (49 CFR Part 173.403(y)), all material with a specific activity less than 2,000 pCi/g is classified as nonradioactive material for transportation purposes (NRT). Components of the Kerr-McGee wastes with specific activities greater than or equal to 2,000 pCi/g are classified as low-specific-activity (LSA) materials and must be shipped in strong, tight containers (49 CFR Part 173.425). Table 5.12 lists the waste components that contain both NRT and LSA materials and gives the amounts and average concentrations of radiological species in the waste components for each classification. The ore tailings and sludge piles and all pond 1 sediments are classified as LSA material because almost all individual samples have specific activities greater than 2,000 pCi/g (Kerr-McGee 1986). All other waste components are NRT material.

Transport of the Kerr-McGee wastes would result in members of the general public being exposed to radiation. Radiation doses would be incurred as a result of (1) direct exposure to external radiation from radionuclides in the wastes and (2) emissions of radon-222 and radon-220 gases and particulates from moving trucks. The radioactive materials released from moving trucks could be absorbed by plants and animals and enter the food chain. Thus, two different radiation doses from transportation of the LSA and NRT wastes were estimated: (1) the radiation dose resulting from external exposure and (2) the 100-year environmental dose commitment resulting from release of radionuclides from trucks into the environment.

Models developed to estimate the radiological impacts of transporting uranium mill tailings were modified and used for this analysis (Chen et al. 1981; Yuan and Chee 1982). The Chen et al. (1981) model was used to estimate



Figure 5.2. Proposed Routes for Transporting the Wastes from the West Chicago Site to the Alternative Sites.

Table 5.12. Classification of Some Components of the Kerr-McGee Wastes for Transportation Purposes^a

Source and Type of Material ^b	Number of Samples	Volume (m ³)	Average Concentration (pCi/g)				
			Uranium-238	Radium-226	Thorium-232	Thorium-230	Radium-228 ^c
<u>Factory Site</u>							
Contaminated soil							
LSA material	97	37,600	173	34	565	66	565
NRT material	264	102,300	99	5.2	34	4.0	34
<u>Disposal Site</u>							
Ponds 2 and 3							
LSA material	41 ^d	6,100	51	21	333	39	333
Ponds 4 and 5							
NRT material	27 ^d	3,800	139	2.4	26	3.0	26
Contaminated soil							
LSA material	24	3,700	119	433	1,130	132	1,130
NRT material	147	23,000	30	4.9	34	4.0	34

^a The 2,000 pCi/g criterion was applied as follows: uranium-238, radium-226, thorium-230, and thorium-232 concentrations were multiplied by respective factors of 4, 9, 1, and 10, and the results were added together to account for intermediate radioactive decay products. If the total was above or below 2,000 pCi/g, then the sample or waste component was above or below the criterion. This procedure was applied to the average concentrations given in Table 2.3 for each component. If the component was above criterion, then the procedure was applied to the individual sample concentration data given by Kerr-McGee (1986--Vol. VIII, Exhibit I), which was used to generate the averages in Table 2.3. The samples were accordingly divided into two groups, above criterion and below criterion, and averages were computed for each group.

^b LSA = low-specific-activity material; NRT = Nonradioactive material for transportation purposes.

^c Concentrations assumed to be equal to those for thorium-232.

^d Sample numbers refer to the total number of samples taken from ponds 2 and 3 and from ponds 4 and 5. Because pond sediments are semisolid, it was considered appropriate to apply the criterion to average concentrations for each pond and classify all the sediments in a pond as either above or below criterion.

external radiation doses, whereas the Yuan and Chee (1982) model was used to estimate doses resulting from dispersion of radon-222 and radon-220 gases and particulates from the transported wastes. It was assumed that for every 160 km (100 mi) traveled, 0.1% of the unpackaged wastes would be dispersed as particulates and gases during transport to each alternative site. These release fractions were based on the assumption that covers would be utilized on the vehicles transporting the unpackaged wastes, minimizing the amount of material lost during transport. There would be minimal releases of radioactive particulates or gases from the packaged wastes; thus, packaged wastes would contribute to exposure only via direct radiation. Waste packaging, trip distances and durations, and other pertinent input parameters used to estimate radiation doses to the public from truck transportation of the Kerr-McGee wastes are presented in Table 5.13.

The estimated doses to the general public and to the maximally exposed individuals associated with transport of the Kerr-McGee wastes are summarized in Table 5.14. These doses would result primarily from releases of radioactive gases and particulates to the environment during transportation. The largest radiation doses would be associated with transport of the wastes to an active surface coal mine (Alternative A), primarily because of the longer distance involved. The radiation doses associated with the transport of the wastes to a reclaimed surface coal mine (Alternative B) would be slightly lower than those for Alternative A because the transportation distance is 10 km (6.2 mi) shorter. The doses from transporting wastes to the underground mine (Alternative C) would be slightly less than those for Alternatives A and B, primarily because the population density is about the same and the transportation distance is slightly shorter. The smallest radiation doses would result from transporting the wastes to the farmland site (Alternative D); these doses would be about half that of the dose for Alternative A, B, or C.

During transport of the wastes, it is possible that an accident might occur, resulting in the release of radioactive materials. The accident rate for trucks transporting radioactive materials, 1.06×10^{-6} accidents per vehicle-kilometer, was taken from a report of the U.S. Nuclear Regulatory Commission (1977). Not all of these accidents would be expected to result in release of radioactive material. Because the LSA materials would be packaged, the likelihood of a release occurring during an accident would be lower for LSA materials than for NRT materials. In this analysis, it was conservatively assumed that 20% of the accidents involving transport of LSA wastes would result in release of radioactive material and 50% of the accidents involving transport of NRT materials would result in release. These rates and the total distances traveled for the various alternatives were used to calculate the estimated number of accidents involving release of radioactive materials; the results are given in Table 5.15.

Table 5.13. Summary of Major Input Parameters for Estimating Radiation Doses Resulting from Truck Transport of the Kerr-McGee Wastes

Alternative	Material Transported ^a	Method of Transport	Total Number of Shipments	One-Way Distance (km)	One-Way Time (h)	Stop Time per Shipment (h)	Average Population Density (persons/km ²)			
A	LSA	Packaged	7,500	290	4.1	0.5	90			
	NRT	Bulk	16,000	290	4.1	0.5				
B	LSA	Packaged	7,500	280	4.0	0.5	90			
	NRT	Bulk	16,000	280	4.0	0.5				
C	LSA	Packaged	7,500	270	3.9	0.5	90			
	NRT	Bulk	16,000	270	3.9	0.5				
D	LSA	Packaged	7,500	130	2.0	0.3	130			
	NRT	Bulk	16,000	130	2.0	0.3				

Alternative	Average Concentration (pCi/g) ^b					Inventory per Shipment (Ci)				
	U-238	Th-232	Th-230	Ra-226	Ra-228	U-238	Th-232	Th-230	Ra-226	Ra-228
A	86	720	84	180	1,300	0.0017	0.014	0.0017	0.0035	0.026
	51	37	4.7	8.8	37	0.0011	0.00081	0.00010	0.00019	0.00081
B	86	720	84	180	1,300	0.0017	0.014	0.0017	0.0035	0.026
	51	37	4.7	8.8	37	0.0011	0.00081	0.00010	0.00019	0.00081
C	86	720	84	180	1,300	0.0017	0.014	0.0017	0.0035	0.026
	51	37	4.7	8.8	37	0.0011	0.00081	0.00010	0.00019	0.00081
D	86	720	84	180	1,300	0.0017	0.014	0.0017	0.0035	0.026
	51	37	4.7	8.8	37	0.0011	0.00081	0.00010	0.00019	0.00081

^a LSA = Low-specific-activity material; NRT = Nonradioactive material for transportation purposes.

^b Average concentration calculated from data given in Tables 2.2 and 2.4.

Table 5.14. Estimated Radiation Doses to the General Public and the Maximally Exposed Individual from Transport of the Kerr-McGee Wastes^a

Alternative	Source of Dose ^b	Effective Dose Equivalent to General Public (person-rem)	Dose to Maximally Exposed Individual ^{b,c} (mrem)			
			Effective Dose Equivalent	Bone	Lung	Bronchial Epithelium ^d
A	External radiation	0.72	1.7	1.7	1.7	-
	Radioactive particulates and gases	1,300	7.6	120	200	0.010
	Total	1,300	9.3	120	200	0.010
B	External radiation	0.70	1.7	1.7	1.7	-
	Radioactive particulates and gases	1,300	7.4	120	200	0.010
	Total	1,300	9.1	120	200	0.010
C	External radiation	0.67	1.6	1.6	1.6	-
	Radioactive particulates and gases	1,200	7.1	120	190	0.0096
	Total	1,200	8.7	120	190	0.0096
D	External radiation	0.47	0.78	0.78	0.78	-
	Radioactive particulates and gases	860	3.4	56	91	0.0046
	Total	860	4.2	57	92	0.0046

^a All doses reported to two significant figures.

^b It was assumed that the external radiation dose to bone and lung is approximately equal to the effective dose equivalent.

^c The maximally exposed individual for every alternative was assumed to be (1) an individual traveling in the same direction as the transportation truck (3 m behind) for the calculation of external radiation doses and (2) an individual located 30 m from the transportation route for the calculation of doses resulting from radioactive particulates and gases.

^d Dose resulting from inhalation of short-lived radon-222 and radon-220 decay products.

Table 5.15. Estimated Potential Number of Transportation Accidents Involving Release of Radioactive Materials and Resultant Doses to the General Public^a

Alternative	Material Transported	Total Number of Shipments	One-Way Distance (km)	Total One-Way Distance Traveled (km)	Potential Number of Accidents Involving Release of Radioactive Material ^b	Spilled Material as Fraction of Total for Estimated Number of Accidents Involving Releases ^c	Effective Dose Equivalent to General Public from Potential Transportation Accidents ^d (person-rem)
A	LSA	7,500	290	2.2×10^6	0.47	1.3×10^{-5}	0.80
	NRT	16,000	290	4.6×10^6	2.5	7.8×10^{-5}	0.57
B	LSA	7,500	280	2.1×10^6	0.44	1.2×10^{-5}	0.74
	NRT	16,000	280	4.5×10^6	2.4	7.5×10^{-5}	0.54
C	LSA	7,500	270	2.0×10^6	0.42	1.1×10^{-5}	0.68
	NRT	16,000	270	4.3×10^6	2.3	7.2×10^{-5}	0.53
D	LSA	7,500	130	9.8×10^5	0.21	5.6×10^{-6}	0.50
	NRT	16,000	130	2.1×10^6	1.1	3.4×10^{-5}	0.36

^a All estimates rounded to two significant figures.

^b Based on the following assumptions: (1) accidents occur at the rate of 1.06×10^{-6} per vehicle-kilometer and (2) 20% of the accidents involving LSA material and 50% of the accidents involving NRT material result in release of radioactive material.

^c Based on the assumption that for each accident resulting in material releases, 20% of the LSA material or 50% of the NRT material would be spilled.

^d 1% of the spilled material is assumed to be resuspended.

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If an accident involving loss of contaminated materials occurred, efforts would be taken to minimize doses to the surrounding population. Access to the affected area would be controlled, and the contaminated material would be cleaned up as quickly as possible. The estimated cumulative radiation doses to the general public resulting from such accidents are also given in Table 5.15. The doses from accidents would be small fractions of those that would be incurred from normal transportation conditions. A person standing 1 m (3 ft) from a ruptured LSA bin for 1 hour would receive an external dose of about 3 mrem; a person standing for 1 hour at 1 m (3 ft) from a spill of NRT materials would receive an external dose of about 0.1 mrem.

A summary of the cumulative doses received by the general public from implementation of the various alternatives is given in Table 5.16.

5.9.1.2 Long-Term Period

After remedial actions, all the wastes would be disposed of in containment systems. The only potential radioactive releases from the wastes to the surrounding environment following containment would be radon gases that might diffuse through engineering barriers.

Because of the short half-life of radon-220 (55 s), no significant radon-220 emissions from the disposal cell cover are expected. Therefore, only radon-222 is of concern in the long-term period. The cover of clay and

Table 5.16. Cumulative Doses to the General Public for the Various Alternatives during the Action Period

Alternative	Effective Dose Equivalent (person-rem)		
	Handling Wastes	Transportation	Total ^a
Proposed Action	36	-- ^b	36
A	26	1,300	1,300
B	26	1,300	1,300
C	26	1,200	1,200
D	27	860	890

^a Total may not add due to rounding to two significant figures.

^b The Proposed Action (on-site disposal) does not require transportation of wastes off-site.

soil installed over the radium-bearing material would reduce the release rate of radon-222 gas into the atmosphere. The cover used for the off-site Alternatives A, B, or D is expected to be at least as effective as that proposed for on-site disposal. The surface radon-222 flux from the covered wastes would then be comparable to that expected for the on-site disposal plan. The parameters used to estimate the amount of radon-222 dispersed into the atmosphere for the different containment alternatives are summarized in Table 5.17. The resulting radon-222 fluxes are given in Table 5.18.

Due to the radioactive decay of radium-226, the radon-222 release from each containment system would gradually decrease with time (see Figure 5.3). The estimated average radon-222 fluxes (over the 1,000-year long-term period) at the surface of the intact cover for the Proposed Action and Alternative D are the same -- $0.33 \text{ pCi}/(\text{m}^2 \cdot \text{s})$, because of similar engineering design and climate; the peak fluxes, $0.37 \text{ pCi}/(\text{m}^2 \cdot \text{s})$, would occur at the beginning of the long-term period. These values are about two orders of magnitude less than the design criteria of $20 \text{ pCi}/(\text{m}^2 \cdot \text{s})$ (40 CFR Part 192). For underground disposal (Alternative C), the wastes would be buried about 73 to 91 m (240 to 300 ft) below the ground surface; because radon gases generated from the disposed wastes would decay long before they could reach the ground surface, minimal radiological impacts are anticipated. For deep-trench disposal (Alternatives A and B), the radon flux at the ground surface is also expected to be insignificant due to the great attenuation from the thick clay layer cover (6 m [20 ft]).

The cell cover is designed to have a radon-222 flux of less than $20 \text{ pCi}/(\text{m}^2 \cdot \text{s})$ for up to 1,000 years to be in compliance with EPA standards for disposal of uranium mill tailings. During long-term maintenance, corrective actions would be taken, as necessary, to maintain the integrity of the containment system. However, even if the system was not maintained for 1,000 years, only the upper soil layer of the disposal cell cover would be affected by erosion. Furthermore, complete loss of the topsoil layer would yield a maximum radon-222 flux of less than $1 \text{ pCi}/(\text{m}^2 \cdot \text{s})$ for all alternatives, which is still well below the EPA design limit of $20 \text{ pCi}/(\text{m}^2 \cdot \text{s})$.

Doses during long-term management were calculated in the same manner as those for the action period. Meteorological patterns and population distributions were assumed to be the same as those used for the action period. The estimated doses to the general public for the long term, resulting primarily from radon-222 gas, are given in Table 5.19. The doses to the general public would be indistinguishable from background radiation exposure. The annual effective dose equivalents to potential maximally exposed individuals near the sites would be less than 1 mrem/yr for all alternatives.

Table 5.17. Important Parameters of Wastes and Covers Used for Analysis of Radon-222 Diffusion^a

Layer	Porosity	Moisture (%)	Thickness (cm)	Density (g/cm ³)	Pore Diffusion Coefficient (cm ² /s)
Proposed Action (Disposal cell area = 5.3×10^4 m ²)					
Waste	0.3	15	900	1.6	0.0021
Clay and low-permeability soil	0.3	15	90	1.6	0.0021
Drainage and intruder barrier	0.3	4	90	2.0	0.037
Soil	0.4	7	60	1.6	0.017

Alternatives A and B (Disposal cell area = 2.6×10^4 m ²)					
Waste	0.3	15	1200	1.6	0.0021
Clay	0.3	15	600	1.6	0.0021
Soil	0.4	7	80	1.6	0.017

Alternative D (Disposal cell area = 1.2×10^5 m ²)					
Waste	0.3	15	340	1.6	0.0021
Clay and low-permeability soil	0.3	15	90	1.6	0.0021
Drainage and intruder barrier	0.3	4	90	2.0	0.037
Soil	0.4	7	60	1.6	0.017

^a No cover analysis is needed for underground disposal, Alternative C.

5.9.2 Dose to Workers

The doses to workers during the action period would be incurred from two major activities, waste handling and transportation. Following completion of remedial actions, no significant occupational doses are expected. A summary of the occupational doses for these alternatives is given in Table 5.20.

5.9.2.1 Waste-Handling Activities

Occupational doses related to waste-handling activities could result from three major sources: (1) external exposure, (2) release of radioactively

Table 5.18. Estimated Radon-222 Fluxes for the Various Alternatives during the Long-Term Period

Alternative	Estimated Radon-222 Flux at Cover Surface ^a [pCi/(m ² ·s)]		
	High	Average	Low
Proposed Action	0.37	0.33	0.30
A	- - - - -	Negligible ^b	- - - - -
B	- - - - -	Negligible ^b	- - - - -
C	- - - - -	Negligible ^b	- - - - -
D	0.37	0.33	0.30

^a The high value would occur at the beginning of the long-term period (following remedial action) and the low value would occur after 1,000 years; the average value is the time-averaged value over the 1,000-year period.

^b Due to the thick overburden (6 m of clay for Alternatives A and B, and 80-100 m of burial depth for Alternative C), radon-222 emissions from the buried wastes into the atmosphere are expected to be minimal.

contaminated particulates, and (3) release of radon-220 and radon-222 gases. The first source would result in an external dose whereas the second and third sources would result in doses to internal organs via inhalation of radionuclides. Among these, external exposure is the major component of the occupational dose commitment.

External doses to the workers were calculated by multiplying the length of time workers would spend in various radiation fields by the radiation field strength and summing over the number of workers involved. For purposes of dose calculations, exposure rate survey data (Kearney 1981) and engineering judgment were used to obtain the best estimates of the radiation fields in which various tasks would be carried out. For work at any of the proposed disposal areas, an average dose rate of 2 mrem/h is expected; this is based on a general exposure rate range of 0.05 to 1 mR/h at the West Chicago Disposal Site, with rates of up to 5 mR/h on the piles, and an estimate that 25% of the work hours would be spent on the piles (5 mR/h) and 75% on the general Disposal Site area (1 mR/h). At the Factory Site, the average dose rate is estimated to be 1 mrem/h, half that at the Disposal Site.

Internal doses were calculated in a similar manner, using the estimated concentrations of airborne radionuclides in the work environment and the

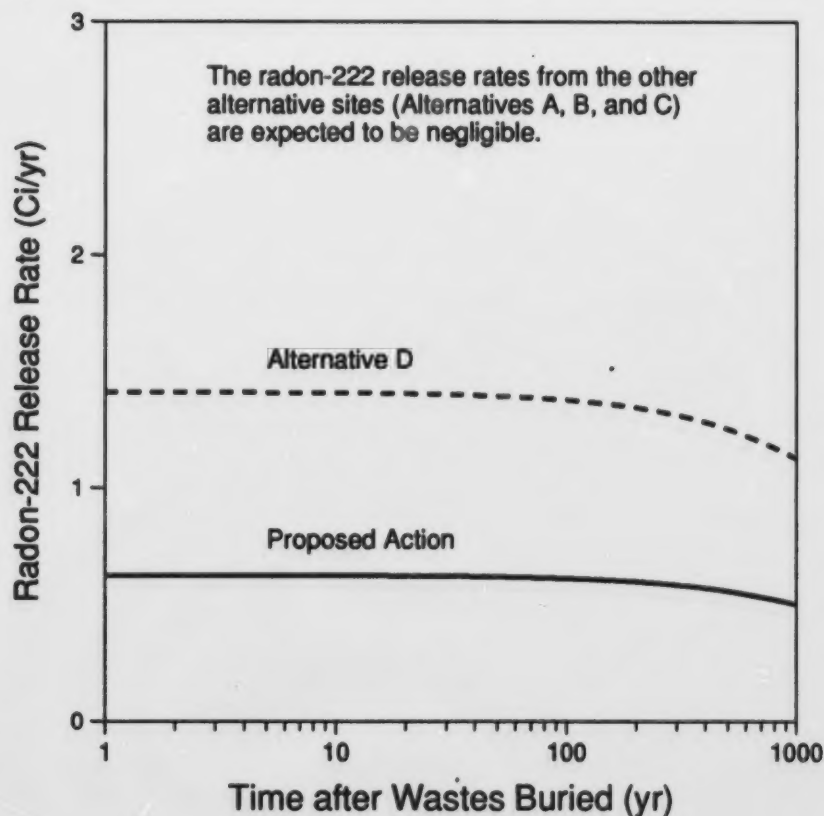


Figure 5.3. Radon-222 Release Rate from Buried Wastes with Cover Intact.

average rates of inhalation. The amount of dust in the vicinity of earth-moving activities has been estimated by NRC to be about 0.01 g/m^3 , with 10% being in the respirable particle-size, i.e., $<10 \mu\text{m}$ in diameter (U.S. Nucl. Reg. Comm. 1980b). In addition, the effect of frequent watering was assumed to further reduce the amount of dust by 50%. The concentration of respirable dust was therefore estimated to be about 0.0005 g/m^3 .

The average concentration of radon-222 decay products to which workers handling the wastes would be exposed is estimated to be 0.002 Working Level (WL),* based on past experience in uranium mills (U.S. Nucl. Reg. Comm. 1980a) and on the radium-226 concentration in the materials. Doses to workers from radon-220 are estimated to be 20% of those from radon-222, based on the relative concentration of radium-228 and radium-226 in the wastes and on the respective half-lives and emanation factors of radon-220 and radon-222.

*1 WL is defined as any combination of radon-222 products in 1 liter of air that will result in the ultimate emission of 0.21 erg of alpha energy.

Table 5.19. Estimated Doses^a to the General Public from Atmospheric Emissions during Long-Term Management^b

Alternative	Site	Effective Dose Equivalent to General Public (person-rem/yr)	Effective Dose Equivalent to Maximally Exposed Individual ^c (mrem/yr)
Proposed Action	West Chicago site	1.8	0.82
A	Active surface coal mine	Negligible ^d	Negligible ^d
B	Reclaimed surface coal mine	Negligible ^d	Negligible ^d
C	Underground coal mine	Negligible ^e	Negligible ^e
D	Farmland site	0.27	0.0068

^a Average doses (over entire long-term management period) to bronchial epithelium due to radon-222 diffusion out of the disposal cell.

^b The 1980 census data were used for the population distributions within 80 km (50 mi) of the sites under consideration. All values rounded to two significant figures.

^c See Table 5.7 for description of maximally exposed individuals.

^d Due to the great attenuation of the thick clay layer in the cover (6 m), radon-222 emissions from the buried wastes into the atmosphere are expected to be minimal.

^e Due to the deep burial depth (80-100 m) for the underground coal mine alternative, radon-222 emissions from the buried wastes into the atmosphere are expected to be minimal.

The occupational doses from handling wastes for all alternatives, based on the work force requirement and the above assumptions, are estimated to range from 550 to 860 person-rem for the entire remedial action period. These doses are summarized in Table 5.20.

5.9.2.2 Transportation

The principal pathway by which drivers transporting the wastes would be exposed to radiation is direct external exposure to the wastes. Doses from exposure to contaminated particulates and radon-220 and radon-222 gases would be negligible. To calculate the dose, it was conservatively assumed that the exposure rate of a worker is the same as the exposure rate at the surface of the waste, i.e., the waste shipment was assumed to be unshielded and no credit was taken for worker distance from the wastes. One driver per truck was also

Table 5.20. Estimated Occupational Doses for the Various Alternatives

Alternative	Effective Dose Equivalent (person-rem)		
	Handling Wastes	Transportation ^a	Total ^b
Proposed Action	610	- ^c	610
A	620	11	630
B	610	11	620
C	550	10	560
D	860	4.9	860

^a Doses to crew members transporting the wastes.

^b Totals may not add due to rounding to two significant figures.

^c The Proposed Action does not require transportation of wastes off-site.

assumed. The cumulative occupational doses are estimated to be 11, 11, 10, and 4.9 person-rem for Alternatives A, B, C, and D, respectively.

5.9.3 Estimation of Health Effects

Health effects in this document specifically refer to the induction of fatal cancers and genetic defects. There have been no direct measurements of increased cancer for low-level radiation exposures; data exist only for higher-level exposures. Risks at lower doses have been estimated by assuming that the same dose/health-effects relationship applies to low doses as to high doses and then extrapolating from data taken at higher dose levels. The cancer risk estimates developed by the National Academy of Sciences (1980, BEIR III report), the International Commission on Radiological Protection (ICRP 1977), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1977) are presented in Table 5.21. The values represent the estimated range of additional cancer mortality (above the normal mortality from such cancers) per 0.5 rem of radiation to a population of one million people continuously exposed to external gamma radiation. Comparison of the values in Table 5.21 indicates that there is general agreement among the estimates developed by the three studies. In applying these estimates, care must be taken to identify the limitations of each study. The UNSCEAR and ICRP approach provides average lifetime risk factors. The UNSCEAR report discusses absolute risk, or the number of expected cancer cases that would

Table 5.21. Estimated Cancer Mortality from Exposure to Low-Level Radiation

Source	Number of Additional ^a Fatal Cancers Estimated to Result from Continuous Exposure of One Million People to 0.5 rem of External Gamma Radiation
National Academy of Sciences (1980)--BEIR III	33-85
International Commission on Radiological Protection (1977)	50
United Nations Scientific Committee on the Effects of Atomic Radiation (1977)	38-88

^a Additional means above the normal cancer mortality.

Source: U.S. Department of Energy (1983).

result from exposure of a given population. The BEIR III report considers both absolute and relative risk. Relative risk is the ratio of incidence of cancer in an exposed population to the incidence in a control population.

The values given in Table 5.21 are considered by many radiation protection specialists to be the best estimates that can be provided. Press releases have publicized radiation-effects studies in which the authors have indicated that the risk is much higher. For example, epidemiological studies on workers from the Portsmouth Naval Shipyards and the Hanford Reservation indicate that a greater risk may exist from radiation exposure than has been reported in the past. The Committee on the Biological Effects of Ionizing Radiation (Natl. Acad. Sci. 1980) reviewed these studies and took the results into consideration in making its recommendations in the BEIR III report.

The American Cancer Society (1978) indicates that about half of all cancer cases are fatal. Thus, the numbers in Table 5.19 can be multiplied by 2 to estimate the incidence of cancer. These cancers would be in addition to those normally expected in a population. According to the American Cancer Society, the individual risk of getting cancer for any member in the population is 1 chance in 4. The cure rate for these cancers ranges from 90% to 5%, depending on the type of cancer.

Genetic effects can be estimated as a result of exposure of the parents to a given radiation level. The risk estimator for serious genetic effects, as expressed in the first two generations, is about 4×10^{-5} per person-rem (Int. Comm. Radiol. Prot. 1977). The total risk of genetic damage that may be

expressed in all subsequent generations is about twice that which is expressed in the first two generations only.

To estimate health risks to both the general public and workers, the cumulative effective dose equivalents were used. Health effects were estimated by multiplying the risk estimator of 1.7×10^{-4} /person-rem (Int. Comm. Radiol. Prot. 1977) times the effective dose equivalent given in Tables 5.16, 5.19, and 5.20.

Health Effects to the General Public. The major component of the health effects associated with radioactive releases for all alternatives would be the occurrence of cancer; more than 90% of the estimated health effects would be fatal cancers. Estimates of increased risk of adverse health effects to the general public as a result of doses incurred during the action period and the long-term period are given in Table 5.22. During the action period, the estimated number of adverse health effects ranges from a low of 0.0061 (Proposed Action) to a high of 0.22 (Alternatives A and B). The higher health effects are mainly the result of higher transportation doses for Alternatives A and B (see Table 5.16). The other off-site alternatives are expected to result in slightly lower cumulative health effects than Alternatives A or B during the action period.

Table 5.22. Cumulative Health Effects to the General Public

Alternative	Site	Cumulative Health Effects	
		Action Period	Long-Term Management ^a
Proposed Action	West Chicago site	0.0061	0.019
A	Active surface coal mine	0.22	Negl. ^b
B	Reclaimed surface coal mine	0.22	Negl. ^b
C	Underground coal mine	0.20	Negl. ^c
D	Farmland site	0.15	0.0028

^a The health effects would result primarily from radon-222 decay-product doses to the bronchial epithelium.

^b Due to the great attenuation of the thick clay layer in the cover (6 m), radon-222 emissions from the buried wastes into the atmosphere are expected to be minimal.

^c Because of the deep burial for Alternative C (80 to 100 m below ground), which results in negligible radon-222 emissions to the atmosphere, minimal radiological impacts are expected for this alternative.

During the long-term period, the Proposed Action would have the highest risk of increased adverse health effects. Over a period of 1,000 years, the Proposed Action would be expected to result in about 0.019 adverse health effects. The off-site alternatives would be expected to have a much lower likelihood of an adverse health impact. For each alternative, the estimated number of health effects is significantly less than one. It is highly unlikely that there would be any adverse radiogenic health effects to the general public during the long-term period as a result of activities associated with this project.

Health Effects to the Workers. Estimates of increased risk of adverse health effects to workers as a result of doses incurred during the action period are given in Table 5.23. The estimates of adverse health effects for all action alternatives are similar, ranging from a low of 0.097 for Alternative C to a high of 0.15 for Alternative D. It is unlikely that there would

Table 5.23. Estimated Health Effects to Workers during the Entire Action Period

Alternative	Site	Total Health Effects
Proposed Action	West Chicago site	0.10
A	Active surface coal mine	0.11
B	Reclaimed surface coal mine	0.11
C	Underground coal mine	0.097
D	Farmland site	0.15

be any adverse health effects to the work force as a result of implementing any of the action alternatives. Following completion of one of these alternatives, there would be no significant occupational dose commitment.

5.9.4 Mitigative Measures

5.9.4.1 Action Period

Radiation doses to nearby individuals are expected to be incurred primarily through the inhalation pathway. During the action period, particulate releases would occur from earth-moving operations. Although radon-222 and radon-220 gases released from the wastes would decay into their

radioactive decay products and add to the inhalation dose, the dose from them would be small compared to the dose from particulates. Mitigative measures should therefore be directed mainly at health-physics safety procedures and controlling the amount of dust generated from earth-moving activities during remedial actions.

Mitigative measures would include spraying the wastes, at least twice per day, with water or other material known to be effective in controlling dust emissions. Equipment operators will be instructed to keep speeds low and to minimize dusting at the possible expense of time. An ambient air monitoring program under the charge of health physics personnel will be implemented during the time when the wastes were being moved. Details of the operations and monitoring program will be drawn up prior to implementing one of the alternatives.

5.9.4.2 Long-Term Period

In the long-term period, corrective actions would be taken, as necessary, to restore the containment system and to return any dispersed contaminated materials to the disposal cell. The most significant mitigative measure would be implementation of an intensive and extensive environmental monitoring system and frequent monitoring of the condition of the disposal cell.

5.10 UNAVOIDABLE ADVERSE IMPACTS

5.10.1 Topography

Implementation of on-site disposal would create a permanent, rectangular, 12-m (40-ft) high disposal cell at the West Chicago site. The rectangular mound rising above the surrounding natural grade would be distinctly noticeable in the landscape. For Alternatives A, B, or C, no burial mound or significant topographic alteration would occur. For Alternative D, a low, gently sloped disposal cell would be created above the surrounding landscape.

For Alternative B, a large final-cut lake impoundment would be drained and used as a deep-trench burial cell; thus, a lake would be eliminated. For all alternatives, a small permanent detention basin for surface runoff would be constructed at the disposal site; this basin would have standing water in it. Security measures would be necessary to prevent children from playing in or near the pond.

Regardless of which disposal alternative is implemented, clean clay fill material must be brought from off-site to fill in the ponds and excavated areas at the West Chicago site, which would unavoidably disturb the topography at the borrow area.

5.10.2 Air Quality

The unavoidable adverse impacts on air quality would be minor and temporary. During dry periods with high wind speeds, the potential for high particulate releases from loading/unloading would be great. However, these impacts could be minimized with proper precautions and the use of simple and effective control measures, such as wetting and covering the waste materials with tarpaulins.

5.10.3 Socioeconomic

All alternatives would involve temporary socioeconomic impacts such as potential adverse effects due to dust, noise, and traffic; increased costs due to control of fugitive dust; damage to roads; and use of energy resources. There would be no unavoidable adverse impacts associated with demographic issues or taxes at either the West Chicago site or the selected alternative site.

5.10.4 Land Resources

Disposal of the Kerr-McGee wastes at the West Chicago site might continue to have an adverse impact on land values near the site. However, in the long term, the action would be expected to have a positive impact on land values. On-site disposal would involve future restrictions to prevent disturbance of the subsurface at the disposal area. These restrictions could prevent approximately 11 ha (27 acres) of land at the Disposal Site from achieving its best potential use with regard to compatibility with West Chicago land-use plans. If off-site disposal were implemented, the West Chicago site would be released for unrestricted future use, but approximately 8 to 77 ha (20 to 190 acres) of land, depending on the selected alternative, would be permanently restricted from public use at one of the alternative sites (Appendix B, Table B.3).

5.10.5 Historical and Archeological

No unavoidable adverse impacts to significant archeological or historical sites have been identified. However, on-ground surveys of the affected areas could encounter unrecorded archeological sites. In most cases, adverse impacts to sites could probably be avoided through siting modifications. Unavoidable adverse effects could be mitigated through data recovery, although the latter invariably entails loss of materials and information.

5.10.6 Geology and Soils

At the West Chicago site, the natural soils are already highly disturbed and in some areas contaminated. Soils at the Alternative A and B sites have been or would be removed by coal mining operations. At the Alternative C site, the wastes would be placed in an underground mine, and no significant disturbance of the surface soils would occur. At the Alternative D site, approximately 19 ha (47 acres) of farmland would be affected by the disposal cell and ancillary areas, and all of the disposal area would be permanently removed from agricultural use. Hence, the greatest impact to agricultural resources (i.e., soil) would result from Alternative D.

If the Proposed Action were implemented, sand and gravel resources underlying the West Chicago site (C and E strata, primarily) would be eliminated from any future use. For Alternatives A through D, some small coal reserves would be present. A zone of no mining should be created around the disposal cell so that additional coal production would not occur next to the disposal area in the future (the prospect of additional mining is negligible but should be accounted for).

5.10.7 Water Resources

5.10.7.1 Surface Waters

West Chicago Site. Surface water in the area of the West Chicago site is currently in a degraded condition and is used only for accepting municipal and industrial discharge effluents. Nonorganic pollutant discharges from site demolition, burial, and reclamation activities would result in temporary increases in chemical, radioactive, and above-normal suspended solids concentrations in Kress Creek and perhaps in the West Branch DuPage River. However, Kerr-McGee has proposed construction of a site runoff diversion system, including use of a settling pond, to minimize water-quality impacts due to surface runoff. In addition, Kerr-McGee would monitor all liquid discharges into ambient receiving waters to ensure compliance with the limitations described in 10 CFR Part 20 and the National Pollutant Discharge Elimination System (NPDES) permit.

Alternative Sites. The impacts on surface water at the alternative sites would vary with the physical characteristics and design of each disposal cell. Disposal at the underground coal mine (Alternative C) is not expected to result in any adverse impacts on surface water quality. For Alternatives A, B, and D, the disposal operations would result in increases in sediment, chemical, and radioactive concentrations in nearby streams. However, these impacts could be minimized through proper disposal procedures and would be almost entirely eliminated upon completion of disposal operations.

5.10.7.2 Groundwater

West Chicago Site. Because the groundwater in the glacial drift aquifer and nearby dolomite aquifer have already been degraded by past waste-disposal operations at the West Chicago site (Section 4.7.2), none of the current disposal alternatives would result in significant additional unavoidable adverse impacts. Groundwater quality should improve if the on-site disposal alternative is chosen. If off-site disposal is selected, the contaminant source(s) would be effectively removed from the groundwater recharge zones, and water quality should improve, resulting in a beneficial impact.

Alternative Sites. The impacts on groundwater at the alternative site would depend on which site was selected for waste disposal (see Section 5.7.2). Based on modeling results (Appendix E), it is predicted that groundwater standards would likely be exceeded by some chemical elements, and unavoidable adverse impacts on groundwater quality would occur at all of these sites.

5.10.8 Ecology

Temporary loss of habitat would occur at the West Chicago site regardless of whether or not it was selected as the site for waste disposal. Similar loss of habitat would also be expected at an alternative above-ground disposal site. The potential for loss of existing wildlife habitat is: farmland $\geq$ reclaimed surface coal mine $\geq$ active surface coal mine; this is based on assumptions related to the amount of disturbance and/or reclamation that would be present at each of these sites prior to its establishment as a waste-disposal site. For the underground coal mine site, there would be a potential for temporary loss of some terrestrial habitat in the vicinity of the mine entrance.

The temporary loss of habitat would result in the destruction of plants and displacement or destruction of animals inhabiting the affected areas. Animals that inhabit areas around the site(s) could be impacted as a result of noise, dust, visual presence of humans and machinery, and so forth. No adverse impacts to state-listed endangered or threatened species are expected due to siting constraints and/or mitigative measures.

Loss of the West Chicago site ponds and associated biota would occur regardless of which site is chosen for disposal. However, because the pond habitats are not unique and are currently stressed, their loss is not viewed as ecologically significant. At the alternative sites, the potential exists for destruction of small streams, ponds, or wetlands and/or sediment inputs into such habitats. This would depend upon the site chosen and the area within the site where waste-disposal activities would occur. No adverse impacts to listed aquatic species are expected.

5.10.9 Radiological

The cleanup and burial actions for the Kerr-McGee wastes would cause an increase in the air concentrations of radioactive particulates and gases around the disposal sites. This would result in a temporary elevation of the radiation dose rate to members of the general public living adjacent to or near the site(s). However, the increase in radiation dose to any member of the public is not expected to exceed the regulatory limits for radiation protection. The potential radiological impacts would be greatly reduced following completion of any of the alternatives.

Implementation of any of the alternatives would result in workers incurring an occupational dose. However, the doses are not expected to result in any harmful effects because there would be strict observance of all regulatory limits and the as-low-as-reasonably-achievable philosophy.

5.11 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

5.11.1 Land Resources

If the West Chicago site were used for waste disposal, a land area of about 11 ha (27 acres) would be restricted from other uses. Off-site disposal of the wastes would require the permanent commitment of 8 to 77 ha (20 to 190 acres) of land, depending upon which alternative was chosen.

5.11.2 Mineral and Soil Resources

For the Proposed Action, some sand and gravel resources at the West Chicago site would be irretrievably lost. For Alternatives A and B, some coal resources and potential farmland at the mine sites would be irretrievably lost. For Alternative C, some coal reserves would be irreversibly lost, but significant impacts to agricultural production would not occur. For Alternative D, farmland and some deep coal reserves would be irreversibly lost. Regardless of which alternative is implemented, a borrow pit near the West Chicago site would have to be established to provide clean fill material for the site.

5.11.3 Energy

An estimated 1,135,500 L (300,000 gal) of diesel fuel and/or gasoline would be consumed by vehicles in implementing the on-site disposal alternative. This estimate was based on the assumption that the clean clay, fill, and topsoil would be transported by trucks.

If the wastes were transported off-site for disposal, a greater consumption of fuel would be involved. The estimated fuel quantities would be about 3,785,000 L (1,000,000 gal) for Alternative A, B, or C and about 1,855,000 L (490,000 gal) for Alternative D.

5.11.4 Ecology

Demolition of buildings at the West Chicago site would result in loss of habitat for animals that frequent abandoned structures, such as the barn owl; however, despite the likelihood of its presence, this raptor has not actually been sighted in the West Chicago vicinity (FES--Sec. 5.12.4). Conversely, the benefits derived by eliminating abandoned structures and associated habitats (e.g., rubbish piles) that harbor rats and other undesirable species within an urban area would outweigh any adverse biological impacts. No irreversible or irretrievable commitment of resources associated with terrestrial ecology at the alternative disposal sites have been identified.

Loss of the West Chicago on-site ponds and potential loss of small streams, ponds, or wetlands at an alternative site would be the only unavoidable commitment of resources associated with aquatic ecosystems. Loss of the West Chicago ponds is not viewed as ecologically significant, and any losses of aquatic or wetland habitats at the alternative sites would also not be ecologically significant because of the comparatively minor amount of habitat that would be affected. Additionally, new habitat (especially ponds or wetlands) could be created to compensate for any losses related to waste disposal.

5.12 DISCUSSION AND COMPARISON OF ALTERNATIVE SITES

The potential impacts of disposal of the Kerr-McGee wastes at each of the five alternative sites are summarized and compared in Chapter 1, Table 1.2. The major environmental issues considered in the impact assessment include topography, air quality, socioeconomic, archeology, mineral resources, erosion, water resources, ecology, and radiology. The work force and costs required for implementing each disposal alternative were also analyzed. For the convenience of discussion, the above issues were divided into those that are directly related to the radioactively contaminated materials and those that are not.

5.12.1 Nonradiological Impacts

The more significant nonradiological impacts would include changes in topography at the disposal site, transportation problems, impacts to mineral and soil resources, and ecological effects.

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The above-grade disposal cell constructed for the Proposed Action would result in a noticeable change in topographic relief at the West Chicago site. For Alternative B, a lake would be drained and filled in. For Alternatives A, C, and D, very minor or no changes in topography would occur.

The transportation problems associated with each disposal alternative would include periodic road closings, traffic congestion, dust, noise, and damage to roads. These problems are expected to be less severe for the on-site disposal alternative (Proposed Action) than for the off-site disposal alternatives (Alternatives A through D). The off-site alternatives would create more traffic problems at West Chicago than would occur for the Proposed Action because more trucks would be needed to transport the wastes. In addition, the off-site alternatives would create transportation problems at the selected disposal site. Nevertheless, transportation problems are considered to be temporary and mitigable.

Implementation of the Proposed Action would cause the sand and gravel resources at the West Chicago site to be irretrievably lost. Some coal resources would be irretrievably lost if Alternative A, B, or C were implemented, and some farmland would be irreversibly removed from agricultural production if Alternative D were implemented. For any of the alternatives, the resulting impacts to mineral or soil resources are considered to be minor.

Impacts to ecological resources would occur at the West Chicago site whether or not it was designated for waste disposal. These would include temporary loss of terrestrial habitat (permanent loss of terrestrial habitat associated with abandoned buildings) and permanent loss of on-site aquatic habitats. Waste removal and handling would cause the major impacts whereas waste emplacement would primarily delay the reestablishment of terrestrial habitat. If the West Chicago site was chosen for disposal, impacts to the other alternative sites would not occur.

Habitats associated with the Alternative A-D sites would be somewhat similar. Thus, comparative impacts would largely depend on the potential amount of surface land that would be disturbed, coupled with the degree of existing disturbance at the specific area designated for waste disposal.

The underground coal mine site would have the least potential to impact ecological resources. No significant disturbances related to waste emplacement would occur. Above-ground areas associated with the waste-disposal activities would be located in the immediate (and disturbed) mine-mouth area. Fewer potential impacts would occur at the active surface coal mine, especially if the designated disposal area was in an area that had just been mined. If waste disposal was designated for an area of the active mine that

had already been reclaimed, the potential impacts would be equivalent to those for the reclaimed mine alternative. The farmland site would potentially have the greatest extent of detrimental ecological impacts, but the impacts would be minimal.

Over the long term, the underground and surface coal mine sites would have the advantage of biological integrity. The West Chicago and farmland sites would eventually be subject to possible intrusion by burrowing animals and plant roots. Successful long-term control programs to prevent bio-intrusion into above-grade or partial below-grade sites (especially for periods of many years) are uncertain.

During the action period, the main impact on surface water would result from increased sediment loadings and contaminant concentrations in surface runoff from excavation and construction activities at the disposal site. Because of the cell construction activities that would occur at the West Chicago site only for the Proposed Action, the impact at this site would be larger for the Proposed Action than for Alternative A, B, C, or D. This impact is expected to be minimal at the West Chicago site for the Proposed Action and all alternatives because of good housekeeping practices and water control and treatment procedures.

Increased sediment and contaminant loading of runoff along the transportation routes is expected for all off-site alternatives (A-D), but the impact of this runoff on surface water would be minimal. During the 1,000-year period following site closure, maintenance and monitoring activities would minimize the impact on surface water at the waste-disposal sites for the Proposed Action and all alternatives.

For the Proposed Action, the buried wastes at the West Chicago site would have minimal impact on groundwater. Peak concentration contributions of chemical species in the groundwater from leaching of the buried wastes are predicted to be 3% or less than the Illinois general use standards and the EPA groundwater protection standards. The one exception is cyanide, which is predicted to reach a peak concentration that is 13% of the Illinois standard of 25 $\mu\text{g/L}$ (Table 2.9).

During the 1,000-year period following site closure, leaching of the buried wastes would have some impact for Alternatives A-D because peak concentration contributions of several chemical species are expected to exceed the Illinois general use standards and the EPA groundwater protection standards. These species are listed in Table 5.6. For Alternative A, peak concentration contributions of cadmium, copper, lead, mercury, and cyanide would exceed the regulatory standards; for Alternative D, peak concentration contributions of arsenic, cadmium, copper, lead, and cyanide would exceed the regulatory

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standards. Alternative B would be slightly better because fewer elements would exceed regulatory standards, i.e., only cadmium, copper, lead, and cyanide would have peak concentration contributions above the standards. For Alternative C, cyanide is the only element that would have a peak concentration contribution above the regulatory standards. Lead and cyanide would exceed the standards by the largest factors, ranging from 1.1 (Alternative B) to 8 (Alternative A) for lead and from 8.8 (Alternative C) to 39 (Alternative D) for cyanide. The relevant groundwater standards are 50 $\mu\text{g/L}$ (EPA) for lead and 25 $\mu\text{g/L}$ (Illinois general use) for cyanide (Tables 2.8 and 2.9). These conclusions are considered to be reliable for the Proposed Action because the model assumptions and parameter values tend to be conservative and site-specific data are available. The conclusions are less reliable for the Alternatives A-D because of the lack of site-specific data and uncertainties in the values of the model parameters. More details are given in Appendix E.

5.12.2 Radiological Impacts

Radiological impacts would consist of (1) radiation doses to members of the general public both during and after the action period and (2) radiation doses incurred by the workers implementing one of the alternatives. The major sources of population exposure would be airborne emissions associated with excavation activities at the West Chicago site and during transportation (for Alternatives A-D). Short-term doses to the general public from waste-handling activities are estimated to be 36 person-rem for the Proposed Action and 26 to 27 person-rem for Alternatives A-D (Table 5.11). Doses to the general public from transportation are estimated to be 1,300 person-rem for Alternatives A and B, 1,200 person-rem for Alternative C, and 860 person-rem for Alternative D (Table 5.14). The total doses to the general public (short-term plus transportation) are therefore estimated to be 36 person-rem for the Proposed Action, 1,300 person-rem for Alternatives A and B, 1,200 person-rem for Alternative C, and 890 person-rem for Alternative D (Table 5.16). None of these doses would be expected to produce any excess adverse health effects.

The radiological impacts would be dramatically reduced following completion of remedial activities. The potential for leaching of contaminants into groundwater would be significantly reduced for all alternatives. The only release would be emissions of radon-222 gas to the atmosphere. The annual dose to the general public in the vicinity of the West Chicago site is estimated to be 1.8 person-rem/yr following completion of the Proposed Action. The annual long-term bronchial epithelium doses to the general public are estimated to be negligible for Alternatives A, B, and C. The annual long-term dose for Alternative D is estimated to be 0.27 person-rem/yr (Table 5.19). These doses represent insignificant increments to the radiation dose received

from background sources of radioactivity and are not expected to result in any adverse health effects.

The occupational doses would be somewhat larger for the off-site alternatives than for the Proposed Action because of the doses incurred by transportation workers. The occupational doses are estimated to be 610 person-rem for the Proposed Action, 630 person-rem for Alternative A, 620 person-rem for Alternative B, 560 person-rem for Alternative C, and 860 person-rem for Alternative D (Table 5.20). Most of these doses would result from waste-handling activities, and the remainder would be incurred during transportation. These doses are not expected to produce any adverse health effects.

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6. ENVIRONMENTAL EFFECTS OF ACCIDENTS

The accidents associated with equipment dismantling, building demolition, and on-site earth-moving activities have been discussed in detail in the FES (Sections 6.1 and 6.2). The accidents associated with off-site transportation of waste materials have been updated based on current waste amounts and the distances to alternative sites: the results are presented below. The safety procedures to prevent or minimize accidents have been discussed in the FES (Section 6.3).

6.1 ACCIDENTS ASSOCIATED WITH OFF-SITE TRANSPORTATION

For the off-site alternatives, about 500,000 MT (550,000 tons) of tailings, building rubble, contaminated earth, and other waste materials would be transported from the West Chicago site in trucks about 20 to 22 MT (22 to 24 tons) in size. This size is preferable because of the limited maneuvering room around the factory. Based on published accident statistics (U.S. Nucl. Reg. Comm. 1977), the probability of a truck accident averages $1.06 \times 10^{-6}/\text{km}$. Not all of the potential accidents are expected to result in release of radioactive materials. Because the LSA materials would be packaged, the likelihood of a release occurring during an accident would be lower for LSA materials than for NRT materials. It was assumed that 20% of the accidents involving transport of LSA wastes and 50% of the accidents involving transport of NRT materials would result in release of radioactive materials; the rates were conservatively estimated based on reported data (U.S. Nucl. Reg. Comm. 1977), and they represent average values for all severity accidents, with an overall accident rate of $1.06 \times 10^{-6}/\text{km}$. Using these rates and the total distances traveled for the various alternatives, the expected number of accidents involving release of radioactive materials was calculated to be about three for Alternatives A, B, and C, and about two for Alternative D (see Section 5.9.1.1).

If an accident involving loss of contaminated materials occurred, efforts would be taken to minimize doses to the surrounding population. Access to the affected area would be controlled, and the contaminated materials would be cleaned up as quickly as possible. It was assumed that if releases of contaminated materials occurred in an accident, 20% of LSA materials and 50% of NRT materials would be spilled. The cumulative radiation doses to the general public from such accidents are estimated to be about 1.4, 1.3, 1.2 and 0.9 person-rem for Alternatives A, B, C, and D, respectively (see Section 5.9.1.1). The estimated population doses from accidents are small fractions of those that would be incurred from normal transport conditions.

6.2 REFERENCE

U.S. Nuclear Regulatory Commission. 1977. Final Environmental Statement on the Transportation of Radioactive Materials by Air and Other Modes. NUREG-0170. Office of Standards Development. Vol. 1. December 1977.

7. MAINTENANCE AND MONITORING

7.1 AIR QUALITY

On-site monitoring for nonradiological air pollutants should be carried out at those sites for which pollutant concentrations might exceed air quality standards (Table 4.4). However, according to the numerical data presented in Table 5.2, it would not be necessary to monitor any of the air pollutants because their concentrations are all predicted to be lower than the standards.

7.2 WATER RESOURCES

7.2.1 Decommissioning Monitoring

During the action period for the Proposed Action, a temporary detention, sedimentation, and treatment system would be established for managing runoff (Kerr-McGee 1986--Vol. IX). Any discharge from the system would be monitored to ensure compliance with applicable state and federal criteria for chemicals (Table 2.9) and radioactive species (10 CFR Part 20.106). Releases from this system as well as from the storm sewer outlet to Kress Creek would be sampled quarterly or monthly during excavation and grading activities. Samples would also be collected immediately after periods of heavy rainfall. If rainfall was continuous, sewer samples would be taken on a daily basis. However, if rainfall was intermittent, samples would be taken only during storm flow.

In choosing chemical and radiological parameters for monitoring, special attention should be paid to those parameters that are regulated and are known to be present in the wastes in appreciable concentrations (Table 2.5). This includes parameters such as chromium, copper, cyanide, lead, selenium, silver, and zinc. In addition, occasional sampling for some of the RCRA priority pollutant parameters that are present in the wastes (Table 2.6) is recommended. Several water quality parameters that should be monitored include pH, total dissolved solids, total suspended solids, sulfate, and fluoride. Radiological parameters to be monitored include gross alpha, gross beta, uranium-238, radium-226, thorium-232, thorium-230, and radium-228.

Monitoring of groundwater would be conducted by taking samples from monitoring wells at the Factory and Disposal sites. Samples would be collected monthly to quarterly. Samples would be monitored for the same parameters that would be monitored for in the surface water discharge. In addition, particular attention should be paid to mobile chemical species such as sodium, sulfate, and chloride because elevated concentrations of mobile species would give the first indications of potential contamination of the groundwater. The water levels in the wells would also be monitored and all

analytical results promptly examined and recorded to document the trends affecting the groundwater system.

For Alternatives A-D, a surface water and groundwater monitoring program would be established that is similar to that described for the Proposed Action.

7.2.2 Postdecommissioning Monitoring

The plan developed by Kerr-McGee for maintenance and monitoring at the West Chicago site after site closure considers three time periods (Kerr-McGee 1986--Vol. XI). During the first 5 years, quarterly monitoring of surface water and groundwater would be carried out. Surface water monitoring would be done at a permanent station established at the outlet of the permanent detention pond. During the second 5-year period, monitoring programs would be carried out semiannually. During the last period, which extends beyond 10 years, the frequency of monitoring activities would be determined by the experience gained during the first two periods. Under normal conditions, groundwater monitoring would be performed annually. Monitoring of surface water would be discontinued unless the cell monitoring data indicated that this monitoring was necessary. Table 7.1 lists the chemical and radiological parameters that would be monitored under Kerr-McGee's plan (Kerr-McGee 1986--Vol. XI).

The staff believes that, in general, Kerr-McGee's plan seems adequate. However, parameters that are monitored should include those that are regulated by the state of Illinois (Table 2.9) and the federal government (Table 2.8, 10 CFR Part 20.106, and 10 CFR Part 40 [U.S. Nucl. Reg. Comm. 1986]) and that occur in the wastes at average concentration levels (Table 2.5) that are orders of magnitude higher than the regulatory limits in groundwater (and are more likely to have a significant impact on groundwater quality). These include chromium, lead, mercury, selenium, and silver (listed in Table 7.1), and copper, cyanide, and zinc (not listed in Table 7.1). Radiological parameters include those listed in Table 7.1 and thorium-230. Occasional monitoring should also be carried out for organic hazardous pollutants that have been detected in the wastes (Table 2.6).

Groundwater monitoring for mobile parameters such as sodium, sulfate, chloride, and cyanide is valuable because it serves as an early indicator of groundwater contamination that might result if leaks developed in the disposal cell.

Because the long-term maintenance and monitoring period extends for 990 years beyond the two 5-year periods, caution should be exercised in using prior monitoring results to adjust monitoring frequencies and parameters over

Table 7.1. Radiological and Chemical Parameters That Would Be Monitored by Kerr-McGee in Surface Water and Groundwater at the West Chicago Site^a

Parameter	Surface Water	Ground-water	Parameter	Surface Water	Ground-water
<u>Radiological</u>			<u>Chemical (continued)</u>		
Uranium-238	x ^b	X	Sulfate	X	X
Radium-226	X	X	Chloride	X	X
Thorium-232	X	X	Fluoride	X	X
Radium-228	X	X	Arsenic	-	X
Radium-224	X	X	Barium	-	X
Gross alpha	X	X	Cadmium	-	X
Gross beta	X	X	Chromium	-	X
			Lead	-	X
<u>Chemical</u>			Mercury	-	X
Total dissolved solids	X	X	Selenium	-	X
Total suspended solids	X	- ^c	Silver	-	X
Sodium	-	X	pH	X	X
Potassium	-	X	Specific conductance	X	X
Calcium	-	X	Temperature	-	X
Magnesium	-	X	Water level	-	X
Bicarbonate	-	X			
Carbonate	-	X			

^a Adapted from Kerr-McGee (1986--Vol. XI).

^b X denotes a monitored parameter.

^c A dash denotes a parameter that would not be monitored.

the long term. The reason is that even if a leak developed in the disposal cell, it would take a long time for less mobile contaminants to be detected in the water in the monitoring wells. Lead is of particular note because it has low mobility (Appendix E, Table E.1) and is present in high concentrations in two of the waste components (Table 2.5).

The surface water and groundwater monitoring plans described above for the 1,000-year long-term period for the Proposed Action also seem adequate for Alternatives A-D. Surface water monitoring may not be needed at all for Alternative C because the wastes would be buried deep underground. Also, the duration of the first two time periods, which are 5 years each for the Proposed Action, may have to be changed to reflect groundwater transport

characteristics of the materials underlying the disposal site. There would be no need to carry out frequent monitoring for contaminants in the monitoring well water before the most mobile contaminants could arrive (even if the disposal cell began to leak as soon as it was closed). The groundwater transit time depends on such factors as the location of the monitor wells and the geohydrologic properties of the soils and rock between the wells and the buried wastes. These would be determined by detailed engineering studies carried out if an alternative disposal site were selected.

7.3 CELL INTEGRITY

The disposal cell would be designed and constructed so that ongoing maintenance would not be required to preserve isolation of the wastes. However, after construction, some maintenance of the cell might be required as the vegetative cover became established and unanticipated maintenance needs arose as the cell structure matured. To determine if maintenance would be required, Kerr-McGee has proposed a program to monitor environmental factors that would indicate potential problems with the cell cover -- such as air, subsidence, and vegetative cover. Air samples would be analyzed for radon-222, and vegetation and subsidence would be monitored through visual and surveyed measurements. Cell erosion would be monitored during the vegetation and subsidence visual inspections. Required repairs to the disposal cell would be made as needed. Maintenance activities might include (1) replacement of eroded soil in the affected area(s) and (2) replacement of fill and grade where localized subsidence has occurred or depressions have formed.

The Kerr-McGee monitoring plan would be divided into three periods based on the number and intensity of post-closure activities that would occur (Kerr-McGee 1986--Vol. XI). The first period would extend for 5 years after completion of the disposal cell, when maintenance of the cell would be expected to be required most frequently. The second period would extend for 5 years from the end of the first period. The third period would commence at the end of the second period and would continue for 990 years.

7.3.1 Physical Effects

During the first monitoring period, air quality and subsidence would be monitored quarterly. The cell would be inspected weekly for erosion, and cell maintenance would be conducted as required. During the second monitoring period, air samples would be collected quarterly and subsidence measurements would be made semiannually. Inspections for erosion would be made monthly or after a severe rainstorm or windstorm. Maintenance would be performed as required.

During the third monitoring period, maintenance activities would be curtailed as much as possible. Inspections of the cell would be made at regular intervals; however, no attempt would be made to perform minor repairs to the cell unless the repairs were needed to protect its integrity. The main objective of the early portion of the third monitoring period would be to observe the behavior of the cell under a program of minimum maintenance, to allow the integrity of the disposal cell to be assessed, and to provide information necessary to develop a program for long-term post-closure care and maintenance. During the third period, air samples would be collected quarterly, subsidence measurements would be made annually, and inspection for erosion would be made quarterly. Maintenance would be performed as needed.

The staff believes that the proposed Kerr-McGee program is adequate, especially in the short term, for monitoring disposal cell development and correcting any problems that might develop. The third period of the program would continue indefinitely, with responsibility for long-term monitoring and maintenance of the site passing to the federal or state government. Monitoring and maintenance needs would be reassessed at that time.

7.3.2 Biotic Effects

Monitoring of terrestrial biota at the disposal site would largely be aimed at assessing the establishment and success of the vegetative cover over the disposal cell. The vegetation would be inspected for signs of plant disease and early stages of intrusion by undesirable species. Additional surface inspection would include searches for signs of intrusion by humans or burrowing animals (Kerr-McGee 1986--Vol. XI). Such inspections would be conducted on a regular basis: weekly during the first 5 years, monthly during the next 5 years, and quarterly beyond 10 years. Maintenance would be performed as required, based on site inspections (Kerr-McGee 1986--Vol. XI, Table 11-2).

Two options exist for vegetative cover maintenance at the disposal site: (1) maintain the cover in a tallgrass prairie or (2) establish a prairie condition and allow natural succession to proceed (Kerr-McGee 1986--Vol. XI). For the first option, periodic burning (probably would not be used for the Proposed Action) or mowing on a 2- or 3-year cycle would be necessary to maintain the prairie condition. Additional spot maintenance would be needed to remove woody vegetation, repair the cover, and so forth. If the cover were allowed to undergo natural succession, the site would receive periodic (passive) maintenance to ensure that biotic development on the cover was not compromising the integrity of the disposal cell (Kerr McGee 1986--Vol. XI). These monitoring and maintenance activities would be most applicable to the above-grade disposal site (Proposed Action) and the partial

below-grade site (Alternative D). Less intense activities would be needed at the deep-trench sites (Alternatives A and B) due to the great depth of clay over the wastes. At the underground coal mine site (Alternative C), only occasional monitoring would be needed to ensure that uncontrolled entry into the mine by humans or animals did not occur.

There are no planned monitoring and maintenance activities for aquatic biota.

7.4 RADIOLOGICAL

7.4.1 Predecommissioning Monitoring Programs

Radiological monitoring programs have been conducted by Argonne National Laboratory, the U.S. Environmental Protection Agency, and Kerr-McGee Chemical Corporation. These programs have included sampling and analysis for radon-222, radon-220, and radioactive particulates (Kerr-McGee 1986). The results of these sampling programs indicate that average concentrations of radon gases and radioactive particulates within the site boundary are generally below the maximum permissible concentration (MPC) limits for unrestricted areas. However, concentrations were found to exceed the MPC limits on occasion. At populated areas away from the site, the concentrations of these radionuclides are below the MPC limits. Samples of water from nearby wells indicate that the concentrations of radionuclides in the well water are below the limits for unrestricted areas given in 10 CFR Part 20.

7.4.2 Decommissioning Monitoring

The major impact of decommissioning activities would result from an increase in the amount of windborne particulates. The monitoring program is designed to measure the amount of windborne material and to quickly detect changes in dust-loading levels that might produce significant effects in the environs. Air particulate samplers would be deployed around the site in sufficient numbers at locations that would permit the objectives of the monitoring program to be met.

7.4.3 Postdecommissioning Monitoring

After decommissioning, the air concentrations of radon-222 would be monitored continuously using passive radon monitors as proposed by Kerr-McGee (1986--Vol. XI). Quarterly evaluation of air monitoring results would ensure that the cover was performing as designed and that radon emissions were not higher than the expected low levels. If higher than expected, radon flux measurements on the cell cover would be made to help identify and locate the

problem. The identification and location of cover defects might be accomplished by grab sampling (e.g., scintillation cell method) along with direct visual inspection of the cell and a walk-over gamma survey. Proper corrective actions for any defect of the cell cover would be taken as necessary.

7.5 REFERENCES

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U.S. Nuclear Regulatory Commission. 1986. Uranium Mill Tailings Regulations; Ground-Water Protection and Other Issues: Proposed Rule (10 CFR Part 40). Fed. Regist. 51(130):24697-24715 (July 8, 1986).

8. COST-BENEFIT ANALYSIS FOR THE PROPOSED ACTION AND ALTERNATIVES

8.1. INTRODUCTION AND SUMMARY

8.1.1. Introduction

The following cost-benefit analysis for the Proposed Action and its alternatives is divided into two parts: (1) direct monetary costs and benefits and (2) environmental costs and benefits. Direct monetary costs and benefits consist of money spent to carry out the waste-disposal activities and monetary expenditures avoided by carrying out the activities. Environmental costs and benefits are costs and benefits that cannot be directly converted into monetary values, e.g., changes in topography at the sites that would result from carrying out the waste-disposal activities.

Monetary values have not been assigned to the environmental costs and benefits because of the difficulty in doing so and for the purpose of keeping the presentation consistent. The only exceptions are the radiological costs and benefits for which a monetary factor of \$1,000/person-rem is used (see 10 CFR Part 50, Appendix I).

In order to establish the basis for a cost-benefit study, the situation was analyzed in which the wastes at the West Chicago site would continue to be managed for the indefinite future in the same manner as they are managed at present, with no improvements made. Activities (or the lack thereof) at the various disposal sites for Alternatives A-D were assumed to be those that would take place if no wastes from West Chicago were buried at the sites. This situation, called the no-action alternative, was used only as a basis for the cost-benefit analysis. It has not been considered as an alternative for disposal of the wastes.

Monetary costs and benefits accruing to parties other than the Kerr-McGee Chemical Corporation are not considered. Examples of excluded items are the benefit to the owner of the Rapatee Mine of the avoided cost of restoration of the site containing the pit that would be used for Alternative A or the net cost or benefit accruing to the owner of the farmland site that results from farming the site, which would cease if the site were used for waste disposal under Alternative D.

8.1.2. Summary

The costs and benefits accruing for the Proposed Action and Alternatives A-D are summarized in Table 8.1. For the environmental factors, table entries are given by terms such as some cost, more benefit, and so forth; the

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Table 8.1. Summary of Cost-Benefit Analysis

Alternative	Monetary Costs and Benefits (thousands of 1986 dollars)		Environmental Costs and Benefits							
			Topographic		Air Quality		Political, Socioeconomic		Land Resources	
	Action	Long-Term	Action	Long-Term	Action	Long-Term	Action	Long-Term	Action	Long-Term
Proposed Action	16,000 cost 5,250 benefit	4,400 cost ^a 70,000 benefit ^b	Least cost	Least ^c benefit	Least cost	Least benefit	Less cost	Less benefit	Some cost	Some cost
A	57,000 cost 5,250 benefit	2,200 cost ^a 70,000 benefit ^b	Some cost	Some ^c benefit	Largest cost	Some benefit	More cost	More benefit	Least cost	Least cost
B	57,000 cost 5,250 benefit	2,200 cost ^a 70,000 benefit ^b	Some cost	More ^c benefit	Largest cost	Some benefit	More cost	More benefit	Least cost	Least cost
C	56,000 cost 5,250 benefit	1,100 cost ^a 70,000 benefit ^b	Some cost	Largest ^c benefit	Some cost	Largest benefit	More cost	More benefit	Largest cost	Largest cost
D	55,000 cost 5,250 benefit	4,400 cost ^a 70,000 benefit ^b	Some cost	Some benefit	More cost	Some benefit	More cost	More benefit	More cost	More cost

Alternative	Environmental Costs and Benefits									
	Historical/ Archaeological		Soils		Minerals		Surface Water		Groundwater	
	Action	Long-Term	Action	Long-Term	Action	Long-Term	Action	Long-Term	Action	Long-Term
Proposed Action	No cost or benefit	No cost or benefit	Some cost	Some benefit	No cost or benefit	Some cost	Some cost	Some benefit	Negl. ^d	Largest benefit
A	No cost or benefit	No cost or benefit	Some cost	Some benefit	No cost or benefit	Some cost	More cost	Some benefit	Negl.	Least benefit
B	No cost or benefit	No cost or benefit	Some cost	Largest benefit	No cost or benefit	Some cost	More cost	Largest benefit	Negl.	Some benefit
C	No cost or benefit	No cost or benefit	Some cost	Some benefit	No cost or benefit	Some cost	More cost	Some benefit	Negl.	More benefit
D	No cost or benefit	No cost or benefit	Some cost	Least benefit	No cost or benefit	Some cost	More cost	Least benefit	Negl.	Least benefit

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Table 8.1. Continued

Alternative	Environmental Costs and Benefits					
	Terrestrial		Aquatic		Radiological	
	Action	Long-Term	Action	Long-Term	Action	Long-Term
Proposed Action	Least cost	Some benefit	Some cost	No cost or benefit	Least cost	Some benefit
A	Some cost	Some benefit	Some cost	No cost or benefit	Largest cost	Some benefit
B	More cost	Some benefit	Some cost	Some cost	Largest cost	Some benefit
C	Some cost	Some benefit	Some cost	No cost or benefit	More cost	Some benefit
D	Most cost	Some benefit	Some cost	No cost or benefit	More cost	Some benefit

^a Values represent the amount required in a sinking fund to pay out the estimated annual maintenance and monitoring costs; a 1% real interest rate and a 5% annual inflation rate are assumed.

^b Value represents the amount required in a sinking fund invested in 1986 to pay the annual cost required over the long-term period, which begins at the end of the action period, to maintain the West Chicago site in its current condition (no-action alternative). A 1% real interest rate and a 5% inflation rate are assumed.

^c The ranking used within each environmental factor is: least < some < more < largest for benefits and for costs. Thus, more costs is more negative than some costs, which is more negative than no costs or no benefits, which is more negative than least benefits, etc.

^d Denotes a negligible benefit.

ordering or ranking of these terms is given in footnote c of the table (details in Sections 8.2 and 8.3). The ordering of terms in the table applies only within each environmental factor (or column). No rankings or relative importance weightings are assigned to the different environmental factors.

Monetary costs and benefits are given separately in Table 8.1 for the action period and the long-term period. For the action period, the costs and benefits are given as total costs in 1986 dollars. In order to convert the annual monetary benefit (Section 8.2.2) to a total action period benefit, the estimated annual benefit was multiplied by an assumed 7-year* duration for the action period. The results indicate that for the Proposed Action and Alternatives A-D, the costs for the action period would be larger than the benefits (which would be the same for each disposal alternative).

Long-term monetary costs and benefits are presented as sinking funds (in 1986 dollars) that would be necessary to pay out the required annual amounts for the 1,000-year period. A 1% real interest rate and a 5% annual inflation rate are assumed (see 10 CFR Part 40, Appendix A, Criterion 10). Over the long term, the monetary benefits would be much larger than the costs. Combination of the action period and long-term period monetary costs and benefits results in a net monetary benefit for the Proposed Action and Alternatives A-D.

For different environmental and monetary factors, different alternatives would be the most preferable in terms of giving the least cost and the most benefit. For example, the Proposed Action would have the least action period monetary cost; however, it would also result in the least benefit to (net improvement of) air quality. Alternative B would have the highest action period monetary cost, but it would result in the largest benefit to soil resources (net reduction in soil erosion).

In order to combine the entries in Table 8.1 into an overall ranking for the alternatives, the environmental and monetary factors must be weighted in terms of their relative importance. This is difficult to do because there is no agreed-upon set of weighting factors. However, it is of interest to see the effects that different sets of weighting factors have on the ranking of alternatives. To this end, two sets of weighting factors were considered. One was obtained by restricting consideration to the monetary, air quality, groundwater, and radiological factors (as the most important factors) and giving all these factors equal weight (and also giving the action period and long-term factors equal weight). On this basis, the resulting ranking of the

*The value of 7 years is an average of values obtained by appropriate scaling of values given in the literature for similar types of waste management.

alternatives is as follows. The Proposed Action would be the most preferable, and Alternative C would be the next in order of preference, followed by Alternative D. Alternative A would be the least preferable, and Alternative B would be only slightly more preferable than Alternative A.

Another estimate of weighting factors was obtained by giving all the monetary and environmental factors listed in Table 8.1 equal importance and equal weight (and giving equal weight to the action period and long-term factors). This estimate results in a ranking in which the Proposed Action would still be the most preferable alternative. However, now Alternative B would be next in order of preference, followed by Alternative C. Alternative A would be slightly less preferable than Alternative C, and Alternative D would be least preferable. Alternative C decreases in the ranking because it would have the largest land resource cost, and Alternative B increases in ranking because of the benefits to soil and surface water resources that would result from the use of spoil hills to construct the waste pile cover (and thereby reduce erosion and sediment loading of runoff). Alternative D would have large land resource costs and more long-term soil erosion and sediment loading of runoff than the other alternatives.

8.2 MONETARY COSTS AND BENEFITS

8.2.1 Monetary Costs

A summary of cost estimates for the various activities associated with the different alternatives is given in Table 8.2. Details and supporting information are given in Appendix F. The costs represent only rough estimates and are rounded to two significant figures. The total cost is expected to be accurate to within a factor of about $\pm 40\%$.^{*} For example, the range of \$9,600,000 (16,000,000 - 40%) to \$22,000,000 (16,000,000 + 40%) for the Proposed Action is expected to include the true cost.

Cost estimates for some activities are not included in the values given in Table 8.1 because sufficient details are not available. These activities include treatment and disposal of water at the West Chicago site and the alternative disposal sites, truck washdown and decontamination, and some site preparation activities (see Appendix F).

^{*}The 40% factor is a judgmental estimate that is based on the fact that, besides a 15% contingency factor -- which is considered appropriate for conceptual estimates (Means Co. 1986) -- there are other uncertainties. These include activities for which sufficient information is not available to make cost estimates, assumptions about the type and size of equipment to be used, distance to the borrow pits, etc.

Table 8.2. Summary of Cost Estimates for the Different Alternatives^a

Activity	Cost (thousands of 1986 dollars)				
	Proposed Action	Alternative A	Alternative B	Alternative C	Alternative D
<u>Site Preparation</u>					
Land acquisition	NA ^b	8	16	460	71
Other	160	200	210	310	470
<u>Cell Construction</u>					
Floor	1,100	38	38	NA	2,400
Sidewall or berm	4,500	420	420	NA	NA
<u>Waste Excavation, Packaging</u>	0 ^c	2,300	2,300	2,300	2,300
<u>Transportation</u>					
Bins	NA	19,000	19,000	19,000	19,000
Truck trips	NA	22,000	21,000	23,000	14,000
<u>Waste Placement</u>	3,000	1,200	1,200	2,900	1,200
<u>Cell Cover</u>					
Temporary	740	NA	NA	NA	NA
Permanent	2,700	3,300	3,300	NA	7,700
<u>Site Restoration</u>					
West Chicago site	2,000	3,100	3,100	3,100	3,100
Alternative site	NA	31	31	0 ^d	75
TOTAL, Activities	14,000	52,000	52,000	51,000	50,000
General Contractor's Fee	1,400	5,200	5,200	5,100	5,000
TOTAL, Action Period	16,000	57,000	57,000	56,000	55,000
Cost Range	9,600-22,000	34,000-80,000	34,000-80,000	34,000-78,000	33,000-77,000

Table 8.2. Continued

Activity	Cost (thousands of 1986 dollars)				
	Proposed Action	Alternative A	Alternative B	Alternative C	Alternative D
<u>Maintenance, Monitoring, and Surveillance (MMS)^e</u>					
Annual Cost ^f					
First 5 years	160	80	80	40	160
Next 5 years	80	40	40	20	80
Next 990 years	40	20	20	10	40
TOTAL, MMS	41,000	20,000	20,000	10,000	41,000
Cost Range	12,000-70,000	6,000-34,000	6,000-34,000	3,000-17,000	12,000-70,000
Sinking Fund	4,400	2,200	2,200	1,100	4,400

^a Values rounded to two significant figures.

^b NA means not applicable.

^c Excavation costs included in waste emplacement cost.

^d Because the wastes would be buried underground, site restoration costs at the disposal site are expected to be small.

^e Activities are assumed to last for 1,000 years.

^f Values refer to 1986 and are not discounted to the actual date at which the MMS activities start.

Source: Appendix F, Tables F.1, F.2, F.3, and F.4.

A comparison of the costs for the different alternatives shows that the Proposed Action would be the least expensive at \$16,000,000 because there would be no transportation costs. The other alternatives, which include transportation costs, would have total costs that are about the same -- \$57,000,000 for Alternatives A and B, \$56,000,000 for Alternative C, and \$55,000,000 for Alternative D. The uncertainties associated with the estimates for Alternatives A-D result in a range of $\pm 40\%$, or \$33,000,000 to \$80,000,000; this cost range is expected to include the actual cost for these alternatives.

A main item of expense would be the cost of bins, \$19,000,000. Bins would be needed to transport the wastes that are classified as low-specific-activity (LSA) wastes by the U.S. Department of Transportation; such wastes must be shipped in strong, tight containers (49 CFR Part 173). The bin cost assumes that the bins would be used once because they would be buried, unopened, in the disposal cell. This cost could be reduced significantly if it were possible to reuse the bins. Another possibility would be to import sufficient amounts of clean material to mix with the wastes at West Chicago to reduce the activity sufficiently to remove the LSA classification. However, the savings from avoiding the use of bins would be reduced by the cost of importing clean material and mixing it with the LSA wastes* and increased transportation costs.

The \$21,000,000 to \$23,000,000 cost of transporting the wastes by truck for Alternatives A-C and the \$13,000,000 cost for Alternative D are also significant. The cost for Alternative D would be lower than for the others requiring transportation because the proposed Alternative D disposal site is closer to West Chicago than the other alternative sites.

Cost estimates for activities other than transportation vary among the alternatives. The permanent cell cover cost for Alternative D, \$7,700,000, is high compared with that for the Proposed Action, \$2,700,000, because the cover in Alternative D would have a larger area than that for the Proposed Action.

The cost of waste emplacement for Alternative C, \$2,900,000, is higher than that for Alternative A, B, or D (\$1,200,000) because it would involve placing the wastes underground in one or two mined-out panels of a coal mine. The waste-emplacement cost for the Proposed Action, \$3,000,000, is large because it includes excavation and transportation costs (within the West Chicago site).

*Use of less radioactive material on-site, which would be transported as bulk waste, to mix with the LSA waste would not solve the problem because the resulting larger volume of wastes would still be sufficiently radioactive to require binning for shipment.

Overhead and profit for the subcontractors are already included in the costs for the activities. The general contractor cost of 10% represents the additional costs of activity and support carried out by a general contractor; included are such items as field supervision, main office expense, worker compensation and employer liability, social security, and Medicare (Means Co. 1986).

Maintenance, monitoring, and surveillance (MMS) activities are expected to last for 1,000 years. Activities such as air, surface water, and ground-water monitoring; inspection; and maintenance are expected to be carried out most frequently during the first 5 years when the waste pile is slowly settling, less frequently during the next 5 years, and even less frequently during the balance of the 1,000-year period (Kerr-McGee 1986). This is reflected in the annual costs given in Table 8.2 for the different alternatives. MMS costs for the Proposed Action and Alternative D are estimated to be the highest because the wastes would be placed on or close to the surface, resulting in a relatively high pile. Costs are estimated to be lowest for Alternative C in which the wastes would be placed underground. More details are given in Appendix F.

The cost estimates for MMS activities given in Table 8.2 are expected to be only rough estimates of the actual costs, especially the total costs for the 1,000-year period. Accordingly, a cost range of $\pm 70\%$ is also included. The $\pm 70\%$ cost range, which is a judgmental estimate, is larger than the $\pm 40\%$ range used for the action period costs because of the difficulty in predicting costs over a 1,000-year period.

The sinking fund costs represent the amount of money in 1986 dollars required to be invested in 1986 to pay the estimated annual costs for a 1,000-year period beginning at the end of the 7-year action period. An annual cost inflation rate of 5% for the 17-year period* and a real annual interest rate of 1% (10 CFR Part 40, Appendix A, Criterion 10) over the 1,000-year period and the action period were used to calculate the sinking fund costs.

8.2.2 Monetary Benefits

Monetary benefits represent the costs associated with the no-action alternative. These benefits represent costs that would be avoided by implementation of the Proposed Action or any of the alternatives (A-D). The main item is the annual cost of maintaining the West Chicago site in its current

*17 years is the sum of the duration of the action period and the first two 5-year periods of the long-term maintenance and monitoring period (Kerr-McGee 1986). A definite value for the cost inflation rate is needed for the first 17 years only.

state. This includes carrying out required monitoring and surveillance programs and other activities. Costs of any site improvements are excluded. The annual cost of these activities in 1986 dollars is estimated to be \$750,000 (Denny 1986).

Monetary benefits as avoided costs are assumed to be zero at the other disposal sites because Kerr-McGee Chemical Corporation is not carrying out any activities at the other disposal sites. Within each time period (action and long term), the monetary benefits are assumed to be the same for the Proposed Action or any of its alternatives because these benefits represent costs for avoided activities that would be the same for the Proposed Action or Alternatives A-D.

8.3 ENVIRONMENTAL COSTS AND BENEFITS

8.3.1 Topography

During the action period, there would be a net topographic cost for all alternatives because temporary piles of materials, detention ponds, and buildings would be built. The costs would be larger for Alternatives A-D because these changes would occur at two sites rather than at one. Also waste piles, ponds, and buildings are already present at the West Chicago site.

For the long-term period, a net topographic benefit would accrue to all the alternatives because the piles of rubble and contaminated wastes, sediment ponds, and buildings at the West Chicago site would be cleaned up and the Factory and Intermediate sites would be graded, covered with topsoil, and seeded and mulched. For the Proposed Action, the topographic cost would consist of the presence of the disposal cell on the Disposal Site (even though it would be contoured and covered with grass). For Alternatives A-D, the topographic cost at the West Chicago site would be zero because the disposal area would be restored by grading to the existing contours, covering with topsoil, and seeding and mulching. For Alternative A, there would be a small net topographic cost at the disposal area because a slight mound, contoured and planted with grass, would be present instead of a site restored to blend in with the surrounding landscape. At the disposal area for Alternative B, a lake and some spoil mounds would be replaced by a gently contoured mound planted with grass (Sections 3.4 and 5.1.1.3). This probably represents a net topographic benefit to the site. No topographic cost would occur for the disposal area for Alternative C because the wastes would be buried underground with no change in the surface contour. A benefit would result to the extent that placing the wastes in the underground panel might prevent future collapse or subsidence of the roof (Section 5.1.1.4). For the Alternative D disposal

area, a large, gently contoured mound would replace the current farmland (Section 5.1.1.5), resulting in a small net topographic cost.

8.3.2 Air Quality

During the action period, no benefits to air quality would occur at the disposal areas for the Proposed Action or any of its alternatives. The costs would include increases in air pollutant loadings at the sites; however, the increases would not be sufficient to result in violations of the air quality standards for any of the alternatives. The predicted costs, as incremental increases in air pollutant loadings, to be expected at the different sites are presented in Table 8.3. Ambient air quality data for locations in the general

Table 8.3. Predicted Incremental Increases in Air Pollutant Loadings at the Different Sites

Site	Alternative	Incremental Concentration Increase ($\mu\text{g}/\text{m}^3$)			
		Suspended Particulates		Sulfur Dioxide	
		Annual	24-hour	Annual	24-hour
West Chicago	All ^a	1.4	4.2	3.5	10
Rapatee and Elm mines	A,B	1.9	5.6	4.7	13.4
Murdock mine	C	0.6	1.6	1.4	3.9
Farmland site	D	1.4	4.2	3.5	10

Site	Alternative	Incremental Concentration Increase ($\mu\text{g}/\text{m}^3$)			
		Nitrogen Dioxide (Annual)	Carbon Monoxide (8-hour)	Lead (3-month)	
West Chicago	All ^a	8.4	-	0.04	
Rapatee and Elm mines	A,B	-	0.7	0.05	
Murdock mine	C	-	0.2	-	
Farmland site	D	-	0.5	0.04	

^aThe word "All" means the Proposed Action and Alternatives A-D.

Source: Based on data in Tables 5.1 and 5.2.

areas of the disposal sites are assumed to be representative of air quality at the disposal sites (Section 5.2). The incremental air loadings or costs would be highest for Alternative A or B and lowest for the Proposed Action (because only one site would be involved). Alternative C would have the lowest incremental air loadings of the off-site disposal alternatives. However, all costs for the Proposed Action and its alternatives would be small because addition of the incremental air loadings to background values results in values that are below the regulatory standards (Section 5.2).

During the 1,000-year period, the environmental cost for the Proposed Action would be the small amount of wind erosion from the maintained disposal cell. The benefit, which would also apply to Alternatives A-D, would be the avoided wind erosion at the West Chicago site for the no-action alternative. Combination of the cost and benefit is expected to result in a small net benefit for the Proposed Action. The net benefit is expected to be largest for Alternative C because there would be no cost or benefit to air quality at the disposal site. The net benefits for Alternatives A, B, and D would be less because a minimal disposal site cost would be expected, i.e., more wind erosion would occur from a gently sloping pile than from the sites with no pile present.

8.3.3 Socioeconomic

Implementation of any of the alternatives would have no costs or benefits on long-term population trends. During the action period, increased noise, traffic congestion, road closings, etc., would result in a transportation cost at the West Chicago site for all alternatives and along the highways to and around the disposal sites for Alternatives A-D. The transportation cost would be much less for the Proposed Action than for the other alternatives because only one site would be involved and no off-site transportation of the wastes would occur.

For all alternatives, it is expected that activities at the West Chicago site during the action period would negatively influence property values in the area. Benefits would be expected over the long term. This should be significant for Alternatives A-D because property values around the West Chicago site should rise from current depressed values to near normal values following removal of the wastes. Property values at the alternative disposal sites are not expected to be affected by waste disposal because the site areas are sparsely populated and have few nearby residences (Section 5.3.1).

The effect of implementation of the Proposed Action on the amount of taxes collected would depend on the future use and ownership of the West Chicago site. For Alternatives A-D, removal of the wastes from the West Chicago site and returning the land to private ownership could have a

significant positive benefit on the amount of taxes collected in the area. The amount of taxes collected in the areas of any of the other disposal sites is not expected to be significantly affected by disposal of the wastes at these sites (Section 5.3.1).

8.3.4 Land Resources

Implementation of the Proposed Action would require the permanent commitment of 11 ha (27 acres) of land at the West Chicago site for waste disposal. For all other alternatives, the land at the West Chicago site could be released for unrestricted use, but land resources at the alternative disposal site would be committed permanently to waste disposal. The land resource cost would be highest for Alternative C, in which 76 ha (190 acres) would be committed, and lowest for Alternatives A and B, in which 8 ha (20 acres) would be committed permanently to waste disposal. The land resource cost for Alternative D would be 19 ha (47 acres) (Appendix B, Table B.3).

8.3.5 Historical and Archaeological

There are no known historical or archaeological costs (in terms of damage to cultural resources) or benefits associated with implementation of any of the alternatives.

8.3.6 Soils and Mineral Resources

8.3.6.1 Soils

A cost-benefit analysis of soil resources for the alternatives was made by considering the soil erosion losses at the different sites. During the action period, soil erosion resulting from earth-moving activities should result in net soil resource costs for all alternatives. Good housekeeping practices could minimize these costs.

For the long-term period, costs and benefits were estimated by use of the Universal Soil Loss Equation (Section 5.6). The results are given in Table 8.4 in terms of metric tons/year (MT/yr) of soil erosion. For the Proposed Action, the cost would be the soil erosion loss from the West Chicago site after site restoration; the benefit would be the erosion avoided by cleaning up the site. For Alternatives A-D, the benefits would consist of the soil erosion losses avoided at the disposal site as well as the erosion avoided by cleanup of the West Chicago site. The costs would consist of soil erosion losses at the disposal site and at the West Chicago site (after waste removal and site restoration).

Table 8.4. Estimated Long-Term Soil Erosion Costs and Benefits Associated with the Proposed Action and Its Alternatives^a

Alternative	Estimated Soil Erosion (MT/yr) for the Long-Term Period		
	Cost	Benefit	Net Benefit
Proposed Action	5.1	29	24
A	6.3	30	24
B	6.3	41	34
C	4.6	29	24
D	9.7	32	22

^a Values obtained by use of the Universal Soil Loss Equation (Section 5.6). Values rounded to two significant figures.

All alternatives would result in a net benefit in terms of reduced soil erosion losses (see Table 8.4). This would occur because of the large benefit at the West Chicago site, i.e., a soil erosion loss of 29 MT/yr that would be avoided by cleaning up the site. This benefit would accrue to all the alternatives. Alternative B would have the largest net benefit, 34 MT/yr because of avoided erosion from spoil hills (with relatively large erosion losses) that would be used to make the cover at the disposal site. The Proposed Action, Alternative A, and Alternative C would be equivalent at a net benefit of 24 MT/yr. For Alternative C, the cost of 4.6 MT/yr would result from the soil erosion loss at the cleaned up and restored West Chicago site. The estimated net benefit for Alternative D, 22 MT/yr of avoided soil erosion loss, would be only slightly less than that for the Proposed Action and Alternatives A and C. Because of the large area of the disposal cell cover, Alternative D would have the highest cost of all the off-site disposal alternatives.

8.3.6.2 Mineral Resources

No costs or benefits to mineral resources are expected during the action period for any of the alternatives. For the long-term period, implementation of the Proposed Action is expected to result in only a small cost to mineral resources in the West Chicago area because, although small deposits of sand and gravel could not be mined at the West Chicago site, these deposits are plentiful in the area. Implementation of Alternatives A-D would remove the

possibility of mining coal deposits adjacent to the disposal sites, but there is little likelihood that these deposits would be developed. Consequently, the cost, in terms of mineral resources removed from possible exploitation, would be insignificant for all alternatives.

8.3.7 Water Resources

8.3.7.1 Surface Water

The surface water costs in the form of increased sediment loading in runoff would be limited to the action period for all alternatives. Alternatives A-D would probably be worse than the Proposed Action because there might be some sediment loading of runoff along the transportation routes. Alternative B would be unique because a large amount of runoff would be generated as the lake was drained. For the off-site alternatives, the surface water cost at the disposal site would be least for Alternative C because no cover construction activities would occur.

During the long-term period, the surface water costs would be insignificant because the covers would be actively maintained to minimize erosion. A net surface water benefit should accrue for all alternatives because the erosion and consequent sediment loading of runoff at the disposal sites should be less (because of cover maintenance) than it would be for the no-action alternative at the West Chicago site. Also, the benefit would be enhanced by the fact that sediment loadings of runoff for the no-action alternative at the West Chicago site would consist of contaminated sediments whereas, for all action alternatives, the sediment loadings would consist of clean sediments. For the long-term period, the net surface water benefit would probably be greatest for Alternative B because of the avoided sediment loading of runoff from spoil hills used to construct the cover. The net surface water benefit would be less for the Proposed Action and Alternatives A and C, and least for Alternative D (Table 8.4), assuming that sediment loadings of runoff are proportional to erosion rates.

8.3.7.2 Groundwater

The net cost or benefit to groundwater resources would contain two components for any of the alternatives: (1) the cost, which would be the increased radiological and chemical concentrations contributed by leaching of the buried wastes, and (2) the benefit, which would be the reduction in radiological and chemical concentrations in groundwater at the West Chicago site as the result of cleaning up the site.

A rough estimate of the cost for the different alternatives was obtained by use of the model calculations of peak contaminant concentrations in the

groundwater contributed by leachate from the buried waste (Section 5.7 and Appendix E). The benefit was estimated from similar model calculations carried out for the West Chicago site for the no-action alternative. The results of these calculations represent groundwater contamination that would be avoided by disposing of the wastes under the Proposed Action or any one of Alternatives A-D.

A measure of the net cost or benefit for each alternative was obtained for each contaminant by dividing the predicted peak concentration contribution at the West Chicago site for the no-action alternative by the predicted peak concentration contribution at the disposal site to obtain a benefit-cost ratio. If the value of this ratio is greater than unity, there is a net benefit; if it is less than unity, there is a net cost. The values of these ratios for different contaminants were collected to give a range of benefit-cost ratios for each alternative.

The results of these model calculations show that there would be a net groundwater benefit resulting from carrying out any of the alternatives. Values of the benefit-cost ratio for the Proposed Action range from 600 to 1,900; this range includes a value for each chemical and radiological species considered. For Alternative C, values of the benefit-cost ratio range from 9.2 to 71; for Alternative B, from 3.7 to 32; for Alternative A, from 3.7 to 4.4; and for Alternative D, from 2.7 to 8.5. According to these ratios, the net benefit to groundwater would be greatest for the Proposed Action, much less for Alternative C, even less for Alternative B, and least for Alternatives A and D. However, a net benefit would accrue to all the alternatives because all the values of the benefit-cost ratio are greater than unity. It must be emphasized that these estimates of benefit-cost ratios are subject to much uncertainty because the model calculations contained many assumptions and estimated values of parameters for which experimental data were not available.

8.3.8 Ecological Resources

8.3.8.1. Terrestrial Resources

During the action period, a small net cost to terrestrial resources would be expected because the earth-moving activities at the West Chicago site and other disposal sites are expected to result in negative impacts on resident plant and animal species. The net cost at the disposal sites for the off-site alternatives (A-D) would be greatest for Alternative D and least for Alternative A.

During the long-term (1,000-year) period, populations of different plant and animal species that are resident at the disposal sites are expected to

change. It is difficult to assign a cost or benefit to such changes. Populations of any endangered species that might be found at the disposal sites would probably be negatively affected by the disposal activities, with a resulting cost. In general, plant species that grow at the disposal sites are expected to be similar to those that would grow there after the waste cover was in place. An exception to this could occur at the farmland site where exclusion of farming would result in a grassland or prairie-like plant community with active site maintenance or a forest community with minimal site maintenance.

The only clearly identified benefit would occur at the West Chicago site where the vegetative cover would increase as a result of cleaning up and restoring the site. Thus, a small long-term benefit to terrestrial resources would probably occur for all alternatives.

8.3.8.2 Aquatic Resources

During the action period, a net cost to aquatic resources would result from increased silt and contaminant loadings of ponds, lakes, streams, etc., that would receive runoff from the sites. However, this would cease at the completion of the action period.

No significant long-term cost or benefit to aquatic resources is expected to occur for any of the alternatives. No endangered or threatened species occur in any of the affected water bodies. A small net cost might occur for Alternative B because any aquatic populations existing in the lake occupying the disposal site would be destroyed when the lake was drained.

8.3.9. Radiological

Radiological doses associated with both the action period and the long-term period for each of the alternatives represent a radiological cost. The radiological benefit would be elimination of the dose to the general public associated with the no-action alternative; this dose is considered a benefit because it is a dose that would be avoided by carrying out the Proposed Action or any of its alternatives.

The estimated radiological costs and benefits for the action period and the long-term period for the different alternatives are summarized in Table 8.5. All alternatives would incur a net cost for the action period. The cost would be least for the Proposed Action and most for Alternatives A and B, with intermediate values for Alternatives C and D. The long-term net benefit for the Proposed Action would be slightly less than that for Alternatives A-D; however the differences are within 2% of one another and are insignificant.

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Table 8.5. Radiological Costs and Benefits Associated with Implementation of the Proposed Action and Its Alternatives^a

Alternative	Action Period Dose (person-rem)			Long-Term Period Dose (person-rem/yr)			Break-even Time (yr) ^d	Total Net Benefit	
	Cost ^b	Benefit ^c	Net Cost	Cost	Benefit	Net Benefit		Dose ^e (person-rem)	Thousands of Dollars ^f
Proposed Action	650	180	470	1.8	25	23	20	23,000	23,000
A	1,900	180	1,700	Negl.	25	25	68	23,000	23,000
B	1,900	180	1,700	Negl.	25	25	68	23,000	23,000
C	1,800	180	1,600	Negl.	25	25	64	23,000	23,000
D	1,800	180	1,600	0.27	25	25	64	23,000	23,000

^a Values given to two significant figures.

^b Source: Section 5.9, Tables 5.16, 5.19, and 5.20.

^c Benefit calculated assuming a 7-year duration for the action period and a 25 person-rem/yr dose (FES--Chap. 5) for the no-action alternative.

^d Value obtained by dividing the net action-period cost by the net long-term period benefit. Value is the number of years required before the cumulative radiological cost equals the cumulative radiological benefit.

^e Value obtained by multiplying the annual long-term net benefit by 1,000 (years) and subtracting the net cost for the action period.

^f Value obtained by use of a conversion factor of \$1,000/person-rem (10 CFR Part 50, Appendix I).

Break-even times are also given in Table 8.5 for each alternative. This refers to the number of years required for the long-term benefit to equal the action-period cost. The Proposed Action would have the shortest break-even time of 20 years; Alternatives A and B would have the longest time, 68 years; and Alternatives C and D would have intermediate values. The total cost (action period plus 1,000-year long-term period) is given as a total dose in person-rem and as a dollar cost. A conversion factor of \$1,000/person-rem was used to obtain the cost (10 CFR Part 50, Appendix I). The total values would be essentially the same for the Proposed Action and its alternatives because the dominant component is a benefit (as an avoided cost for the no-action alternative), which would be the same for all.

8.4 REFERENCES*

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*In this reference list, the letter cited is on file. Copies are available upon request from S.Y. Tsai, Energy and Environmental Systems Division, Bldg. 362, Argonne National Laboratory, Argonne, Illinois 60439.

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APPENDIX A. ALTERNATIVE SITE SELECTION PROCESS

APPENDIX A. ALTERNATIVE SITE SELECTION PROCESS

This supplemental alternative site analysis has been prepared in response to the Atomic Safety and Licensing Board's ruling that the staff must supplement the Final Environmental Statement (FES) to evaluate the impacts of permanent disposal of wastes from the Kerr-McGee Rare Earths Facility located at West Chicago, Illinois. Kerr-McGee Chemical Corporation (West Chicago Rare Earths Facility), LBP-85-3, 21 NRC 244, at 256 (1985)]. As part of this supplement, the U.S. Nuclear Regulatory Commission (NRC) staff has independently evaluated the suitability of alternative sites beyond those considered by Kerr-McGee or by the staff in the FES. The wide range of disposal alternatives considered is discussed in this appendix. The discussion includes an analysis of alternative sites within and outside the state of Illinois, an assessment of the advantages and disadvantages of each alternative, the approach and methodology by which these alternatives were evaluated and compared, and the method by which the final alternative disposal categories and sites were selected.

A.1 APPROACH AND METHODOLOGY FOR SELECTION OF ALTERNATIVE CATEGORIES

Generic categories of waste-disposal options were identified by the staff (Table A.1), and reconnaissance-level data and information were gathered pertaining to each of these categories. Considering the geological, hydrological, engineering, transportation, political, social, and economic characteristics associated with each of the disposal options, the staff rated the suitability of each category using the following procedure:

1. Three general criteria were chosen for ranking purposes: geological/hydrological, social/political, and economic. These criteria were considered to be more important than others in the selection of a suitable waste-disposal site.
2. Nine staff members with experience in waste management ranked each of the three criteria for each of the 28 disposal categories, with 1 signifying best conditions and 3 signifying worst conditions.
3. Each staff member then assigned a weighting number that he or she attributed to each of the three ranked criteria. A high percentage signified greater importance and a low percentage signified lesser importance. The three weighting numbers totaled 100% for each staff member.

Table A.1. Potential Off-site Categories for Disposal of the Kerr-McGee Wastes

Site	Relative Ranking ^a			
	Geo./ Hydro.	Soc./ Pol.	Econ.	Total
I. Illinois Sites				
A. Existing low-level waste disposal sites				
1. Sheffield	0.91	1.14	0.33	2.38
B. New Illinois-Kentucky low-level waste disposal site				
	0.55	0.88	0.35	1.78
C. U.S. Department of Energy facilities				
1. Argonne National Laboratory	0.98	0.92	0.28	2.18
2. Fermi National Accelerator Laboratory	0.80	0.86	0.27	1.93
D. Reclaimed surface mines				
1. Coal	0.70	0.56	0.33	1.59
2. Clay/shale	0.60	0.60	0.35	1.55
3. Limestone/dolomite	1.24	0.56	0.37	2.17
4. Sand/gravel	1.29	0.60	0.39	2.28
E. Active surface mines				
1. Coal	0.55	0.81	0.42	1.78
2. Clay/shale	0.55	0.86	0.45	1.86
3. Limestone/dolomite	1.23	0.81	0.48	2.52
4. Sand/gravel	1.29	0.81	0.48	2.58
F. Abandoned underground mines				
1. Coal	0.73	0.56	0.47	1.76
2. Fluorite	0.79	0.56	0.49	1.84
3. Lead/zinc	0.72	0.56	0.51	1.79
G. Active underground mines				
1. Coal	0.67	0.88	0.49	2.04
H. Undeveloped land or farmland				
	0.61	0.76	0.39	1.76

Table A.1. Continued

Site	Relative Ranking ^a			
	Geo./ Hydro.	Soc./ Pol.	Econ.	Total
II. Out-of-State Sites				
A. Existing low-level waste disposal sites				
1. Hanford, Washington	0.49	0.86	0.53	1.88
2. Beatty, Nevada	0.43	0.80	0.51	1.74
3. Barnwell, South Carolina	0.43	0.92	0.51	1.86
B. Remedial action sites^b				
1. FUSRAP sites	0.80	1.1	0.45	2.35
2. UMTRAP sites	0.73	0.92	0.47	2.12
3. Surplus Facilities Management Program	0.80	1.1	0.45	2.35
4. Grand Junction Remedial Action Program	0.72	1.0	0.50	2.22
C. U.S. Department of Energy reservations (e.g., Oak Ridge National Laboratory, EG&G, Nevada Test Site, Savannah River)				
	0.80	0.90	0.47	2.17
D. Surface uranium mine or mill sites				
	0.67	0.59	0.48	1.74
E. Underground mines (active or abandoned)				
	0.70	0.77	0.50	1.97
F. Undeveloped land or farmland				
	0.61	1.0	0.47	2.08

^a Relative ranking is based on the following weighting numbers: geological/hydrological, 0.43; social/political, 0.36; and economic, 0.21.

^b FUSRAP = Formerly Utilized Sites Remedial Action Program;
UMTRAP = Uranium Mill Tailings Remedial Action Program.

4. The percentages for the weighting numbers were averaged for each disposal category, as were the marks for each ranking criterion.
5. The average weighting number for each ranking criterion was multiplied by the respective score for each disposal category. For example, the average geological/hydrological ranking score for reclaimed surface coal mines was 1.63, and the average geological/hydrological weighting number was 0.43; therefore, the weighted geological/hydrological score for reclaimed surface coal mines was $1.63 \times 0.43 = 0.70$.
6. The three weighted scores for each disposal category were added for a final score (see Table A.1). The lowest scores correspond to the best-rated generic disposal categories. The lowest scores resulting from this subjective selection process were as follows:

<u>In-State Categories</u>	<u>Total Score</u>
Reclaimed clay and shale surface mines	1.55
Reclaimed surface coal mines	1.59
Abandoned underground coal mines	1.76
Undeveloped land or farmland sites	1.76
Active surface coal mines	1.78
Illinois-Kentucky low-level compact site	1.78
<u>Out-of-State Categories</u>	
Uranium mine or mill tailings site	1.74
Beatty low-level disposal site	1.74

Four off-site, in-state disposal alternatives were evaluated in detail: active surface coal mines (Alternative A), reclaimed surface coal mines (Alternative B), active underground coal mines (Alternative C), and farmland sites (Alternative D). (Abandoned underground coal mines are not feasible because they are almost always sealed, may have caving problems, or may be partially or completely flooded; therefore, only active underground coal mines were evaluated.) The general areas and sites within the state of Illinois that were evaluated for possible disposal sites and the procedures by which the specific sites were chosen for each disposal category are discussed in Sections A.3 through A.7.

During field investigations and site visits, none of the clay or shale mines evaluated appeared to have the conditions requisite for development of a

waste-disposal facility. As a result, a clay or shale mine was not selected for final evaluation as a disposal alternative. The clay and shale mines investigated and why they seemed inappropriate for waste disposal are discussed in Section A.7.

The Illinois-Kentucky low-level waste compact site was not evaluated further because (1) it will be a newly licensed low-level waste disposal site and the legal or institutional barriers to co-locating thorium mill tailings (non-low-level waste) at a low-level waste site are unknown, (2) the location of the site has not yet been selected, and (3) the disposal costs at this new site could not be estimated.

Currently licensed low-level waste disposal sites (i.e., Beatty, Nevada; Barnwell, South Carolina; or Hanford, Washington), future state compact low-level waste disposal facilities, or a uranium mine or mill tailings site were not considered. The reasons for not considering these sites are discussed below.

The Low-Level Radioactive Waste Policy Amendments Act (LLRWPA) of 1985 (42 U.S.C. 2021b et seq.) defines low-level radioactive waste as radioactive waste that is "not high-level radioactive waste, spent nuclear fuel, or byproduct material (as defined in Section 11e.(2) of the Atomic Energy Act of 1954 (42 U.S.C. 2014(e)(2))." Section 11e.(2) defines by-product material as "the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content." Based upon analysis reflected in the FES (Appendix H, pp. H-2 to H-5), the NRC staff has concluded that the wastes that were generated at and remain on the Rare Earths Facility site should be considered to be by-product material. The LLRWPA returned to each state the responsibility to dispose of low-level radioactive wastes generated in that state. The legislation did not enlarge the authority of the states over radioactive wastes other than low-level. Thus, the LLRWPA does not change existing law regarding wastes such as those at the West Chicago site.

Although the LLRWPA does not require the disposal sites established under that statute to accept 11e.(2) by-product material for disposal, no provision of the statute explicitly prohibits states from accepting these materials. However, even though the LLRWPA does not explicitly prohibit the regional disposal facilities located at Barnwell, South Carolina; Richland, Washington; and Beatty, Nevada; from accepting by-product material for disposal at these facilities, the Act sets certain limitations on the availability of Barnwell, Richland, and Beatty. Under the Act as amended, the state of South Carolina may limit the volume of low-level radioactive waste accepted for disposal at Barnwell to a total of 238,000 m³ (311,000 yd³) of low-level radioactive waste during the 7-year period beginning January 1,

1986, and ending December 31, 1992; the state of Washington may limit the amount of such waste for disposal at Richland to 278,000 m³ (363,000 yd³) during that same period and the state of Nevada may limit the amount of such waste to be disposed at Beatty to 39,700 m³ (51,900 yd³) for that same period. Thus, the three states in which the existing sites are located may limit the total amount of low-level wastes to be disposed of at these sites during the 7 years ending December 31, 1992, to 555,000 m³ (726,000 yd³).

The three existing disposal facilities are required to accept as much as 337,000 m³ (441,000 yd³) of low-level radioactive waste generated by commercial nuclear power reactors during the 7-year interim access period. Thus, the total capacity to which the states in which the interim sites are located may limit disposal is 555,000 m³ (726,000 yd³), of which 337,000 m³ (441,000 yd³) is allocated to reactors. There are 282,000 m³ (369,000 yd³) of waste materials at West Chicago. This is more than the residual capacity of the three interim sites after the reactor allocation is subtracted.

Because the total available capacity of the three interim sites is less than that required to dispose of the Kerr-McGee wastes, disposal at these sites need not be evaluated under the National Environmental Policy Act (NEPA) of 1969 as an alternative to Kerr-McGee's proposed plan to dispose of the waste on-site.

Disposal at one of the interstate compact sites need not be considered as an alternative to on-site disposal at West Chicago because these facilities will not be available in the time frame contemplated for disposal of the Kerr-McGee wastes and because no compact facility would be required to accept these wastes. The Central Midwest Compact, of which Illinois is a member, would not be obligated to accept the Kerr-McGee wastes, even if the Central Midwest Compact facility were ready to accept wastes for disposal in the required time frame. The Central Midwest Compact defines low-level radioactive waste as excluding among other things "by-product material as defined in Section 11e.(2) of the Atomic Energy Act of 1954."

The NRC staff requested that DOE evaluate the possibility of making DOE-controlled land available for disposal of the Kerr-McGee wastes. DOE declined to evaluate any sites under DOE control (Voigt 1985).

The possibility of using surface uranium mines or mill tailings sites located in the West for disposal of the Kerr-McGee wastes was considered but discarded, primarily because of the long travel distances that would result in large costs and increased doses and health risks resulting from transporting the wastes. Typical transportation costs were estimated using a uranium mill tailings site located in Edgemont, South Dakota. The site is operated by the Tennessee Valley Authority and is about 1,450 km (890 mi) from the city of

West Chicago. The results indicate that transport of the wastes would require an estimated 7,450 trips by flatbed truck and 16,100 trips by dump truck for a total of 23,500 truck trips at an estimated cost of about \$63,400,000.

A.2 SOURCES OF DATA AND INFORMATION USED TO MAKE SITE SELECTIONS

The Illinois State Geological Survey (ISGS) and the Illinois State Water Survey (ISWS) have conducted extensive studies of the geology and hydrology of Illinois over the past 75 years. Survey publications cover in various levels of detail almost every part of the state. In addition, the surveys include an extensive collection of drill logs, geophysical logs, and core analyses of water, oil, gas, and coal test wells.

The ISGS has been involved with groundwater research related to municipal and hazardous waste-disposal sites for at least 20 years. Its research, monitoring, and mapping activities in many counties have led to publication of numerous environmental geology reports that discuss proper siting and potential environmental problems related to waste disposal. A color map (Berg and Kempton 1984) and a report with maps (Berg et al. 1984) published by ISGS address the potential for contamination of shallow aquifers from land burial of municipal wastes. The ISGS emphasizes that these maps are "designed for regional evaluations [and] should not be the basis for evaluation of specific sites" (Berg and Kempton 1984). These maps integrate, on a regional basis, what is known about shallow geologic materials, bedrock, and aquifers throughout the state; they were an excellent resource for initial screening of potential sites for waste-disposal facilities.

More recently, the ISGS and ISWS compiled data and developed maps for two different projects related to groundwater protection and waste disposal. Illinois Public Act 83-1268, enacted in August 1984, is directed toward protecting Illinois groundwater from contamination. From efforts pursuant to this Act, data have been compiled and maps generated that show (1) the spatial distribution of groundwater use; (2) the spatial distribution of groundwater quality; (3) the locations of mining, manufacturing, chemical manufacturing, and waste-disposal facilities; and (4) the ranking of target areas for an expanded groundwater quality monitoring network.

The second program of interest, conducted primarily by the ISGS for the Illinois Department of Nuclear Safety, is related to the siting of a new low-level waste disposal facility in Illinois. The objectives of this project are to compile data and prepare maps on aquifers, structural geology, surface-water bodies, sand and gravel resources, coal reserves, and public interest areas that may bear on the siting of a low-level waste facility (Miller et al. 1985).

Staff members made a great effort to locate and use the information discussed above during the description, evaluation, and selection of alternative disposal sites for the Kerr-McGee wastes.

A.3 ACTIVE SURFACE COAL MINE (ALTERNATIVE A)

A.3.1 Introduction

Active surface coal mines in Illinois typically create long (up to several kilometers), narrow (30-40 m) pits that are up to 40 m (130 ft) deep. Once the coal has been removed from a pit, the dragline or shovel moves on to the next cut, and overburden materials are cast into the pit just completed. The spoil materials in the mined area are then graded, covered with topsoil, and revegetated. When a mining operation reaches a permit boundary or a primary road, the mining operation commonly moves elsewhere, and the final pit is either filled in with spoil materials and reclaimed or left open to fill with water to form a lake.

A.3.2 Potential Advantages of Alternative A

The advantages of using a final pit for disposing of the Kerr-McGee wastes are:

- The recoverable coal reserves have been completely removed in the immediate area, and the mining activity has moved to another part of the permit area. Hence, the waste-disposal operations should not interfere with mining activities.
- Coal-bearing Pennsylvanian rocks are the uppermost rock strata in approximately 75% of Illinois and generally have low hydraulic conductivity and low specific-capacity values. In the Illinois Coal Basin, several thousand farms and homes, several hundred small municipalities, and numerous industries obtain groundwater from thin sandstones and limestones of Pennsylvanian age, but wells in these rocks usually yield less than 1.6 L/s and in some areas generally yield less than 0.2 L/s (Csallany 1966; Smith and Stall 1975). The median specific capacity of water wells in Pennsylvanian rocks is 0.072 L/s per meter of drawdown; only 10% of the wells exceeds 0.27 L/s per meter of drawdown (Csallany 1966). Water wells are drilled into Pennsylvanian rock because it is the uppermost bedrock and therefore cheaper to drill, not because these rocks are better aquifers.
- A surface mine pit is large and deep and could easily accommodate the 282,000 m³ (369,000 yd³) of Kerr-McGee wastes. Deep-trench burial is

considered preferable to shallow-trench burial (Bennett et al. 1984; Gilbert and Luner 1985). In particular, the greater depth of burial significantly reduces radon emissions, the possibility of animal or plant-root intrusion into the buried wastes, and the possibility of cap erosion reexposing the buried wastes. The size and depth dimensions typical for final-cut pits of surface coal mines are very similar to those dimensions often suggested for deep-trench burial. Therefore, surface coal mine pits were assumed to be analogous to deep trenches for this study.

- The use of a final pit would mean that one wall of the disposal cell would be formed of low-permeability shale, siltstone, and limestone. In addition, the pit floor of surface coal mines often consists of 1-3 m (3-10 ft) of underclay materials, which are characterized by very low permeability.
- The pit will already have been excavated by the mining company, and any clayey till stockpiled at the side of the pit during mining could be used later as liner and cap material. Hence, an opportunity exists for significantly reduced construction costs.
- Machinery used for coal mining (e.g., dozers and pan scrapers) could also be contracted to construct some or all of the disposal cell. This equipment would be at or near the site. Since these types of equipment are seldom used full time by mining companies, a mutually beneficial relationship between the coal company and Kerr-McGee or its contractor could be negotiated. Such an arrangement could lead to additional cost savings.
- Many active surface coal mines have rail spurs for shipping coal. Thus, it may be feasible to ship the Kerr-McGee wastes to an active mine by rail.

A.3.3 Potential Disadvantages of Alternative A

Although there are several disadvantages of using the final pit of a surface coal mine for waste disposal, they could be completely or nearly completely mitigated by proper site selection and engineering design.

- Kerr-McGee (1980--p. 11.7) mentioned its concern over "fracture permeability persistent in all coal beds." Coal seams always contain some amount of fractures (primary and secondary cleats), but it does

not necessarily follow that all coal seams have high values of hydraulic conductivity (Stone and Snoeberger 1977; Schubert 1980).

- In some surface coal mines, the undisturbed overburden (rock and glacial strata) may have moderate to high hydraulic conductivities (e.g., $>10^{-5}$ cm/s), such that groundwater inflow into the active pits is a nuisance or major problem.
- When the overburden (rock and glacial strata) is displaced by mining, it will have a completely different set of hydraulic properties. The spoil materials are expected to have greater porosity and permeability than the undisturbed strata. In some cases, the spoil materials have extremely high permeability values because they consist of large boulders and cobble-sized sandstone, limestone, and hard-shale fragments.
- Because Illinois coal mine pits are typically 15 to 30 m (50 to 100 ft) deep, the pit floors are almost always below the groundwater table. Hence, deep-trench burial in a coal mine pit probably means that the buried wastes will become saturated with groundwater seeping into the disposal cell over a long period of time after burial.

A.3.4 Selection of an Active Surface Mine

There are only three active surface coal mines located in the northern 80% of Illinois; all of the other active surface mines are in far-southern Illinois. Only the northern mines were examined in order to minimize transportation costs to the site finally selected for evaluation. The Rapatee Mine in northeastern Fulton County is the oldest operation, having opened in 1976. Operations at the Industry Mine, located in south-central McDonough County, began in 1982. The newest surface mine, Cedar Creek in western Schuyler County, opened in 1982. The locations of these mines are shown in Figure A.1. Each of these mines was visited twice. Notes were taken concerning local topography, streams, geology, groundwater conditions, roads, railroads, and population densities. The general characteristics of the three active surface coal mine sites are summarized in Table A.2.

The Cedar Creek Mine was not a good potential site because of (1) the great topographic relief in the area (the mine is located on an upland surrounded by deeply incised stream valleys) and the high potential for long-term erosion, (2) the relatively thin layer of Pennsylvanian shales and clays that lie beneath the mine floor, (3) the permeable Mississippian limestones that directly underlie the Pennsylvanian strata, and (4) the very thin layer of glacial till. The mine is also the farthest from West Chicago and is the

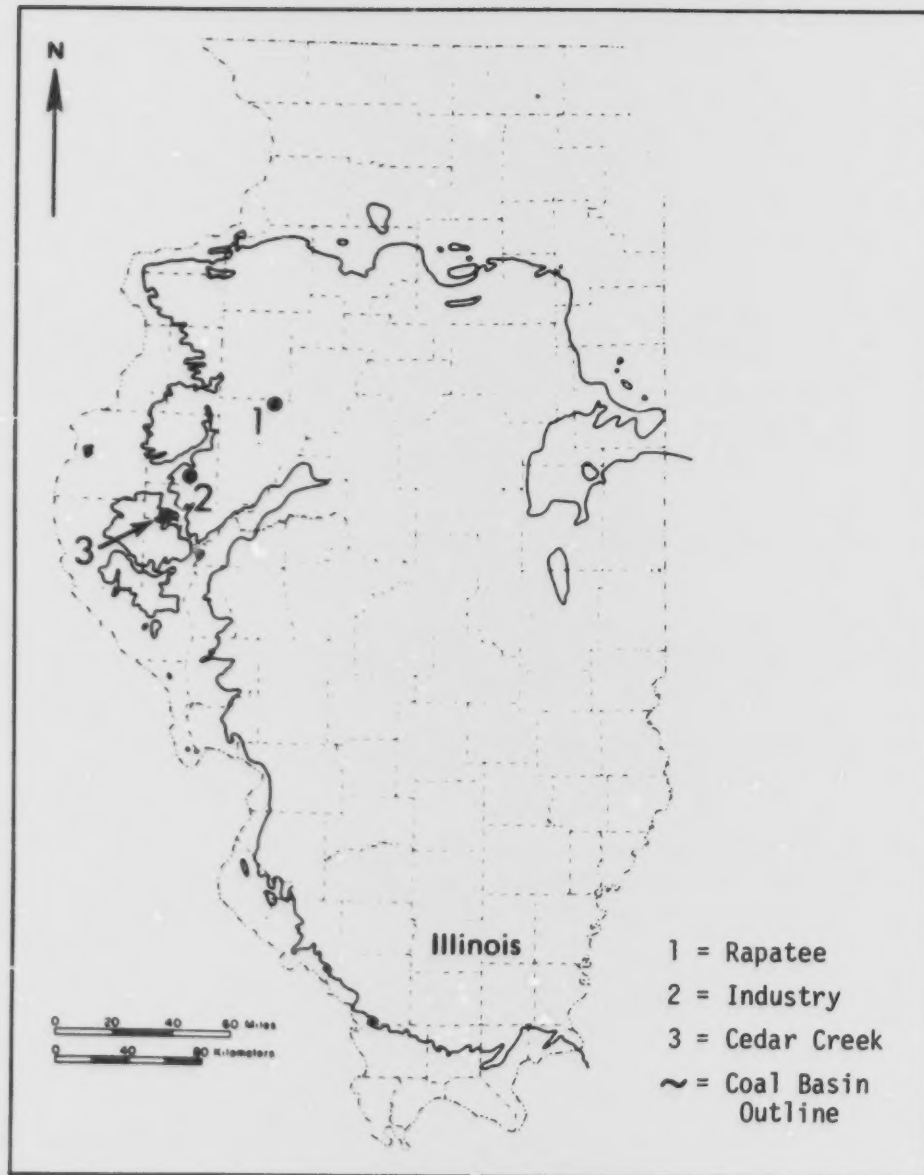


Figure A.1. Locations of the Evaluated Active Surface Coal Mines.

Table A.2. General Characteristics of the Evaluated Active Surface Coal Mines

Characteristic	Rapatee Mine	Industry Mine	Cedar Creek Mine
Mine company	Midland	Freeman United	Black Beauty
County	Fulton	McDonough	Schuyler
Township and range	T8N, R3E	T4N, R3W	T2N, R3W
Nearest towns (1980 population)	Rapatee, Middle Grove (<550)	Industry (600)	Camden (<275)
Nearest streams	Littlers Creek, Coal Creek, Swegle Creek	Grindstone Creek, Willow Creek	Cedar Creek, Little Cedar Creek, La Moine River, Missouri Creek
Linear distance from West Chicago	212 km	277 km	295 km
Highway access	I-80 west, IL 78 south, IL 116 west	I-55 south, U.S. 136 west, U.S. 67 south	I-55 south, U.S. 136 west, U.S. 24 west, U.S. 67 north
Rail access	Chicago and Northwestern	None	None
Coal seam mined	No. 5 and No. 6	No. 2	No. 2
Overburden materials (approximate thick- ness)	Glacial till and loess (5-8 m); shale (10-15 m)	Glacial till and loess (5 m); sandstone (4 m); shale (10 m)	Glacial till and loess (2 m); sandstone (2 m); shale (8 m)
Pennsylvanian thick- ness beneath mine floor	73 m	30 m	30 m
Sub-Pennsylvanian formations	Keokuk and Burlington Limestones (Mississippian)	St. Louis and Salem Limestones (Mississippian)	St. Louis and Salem Limestones (Mississippian)
Primary bedrock aquifer (approximate depth to top and thickness)	St. Peter Sandstone (408 m, 82 m)	Keokuk and Burlington Limestones (90 m, 60 m)	Keokuk and Burlington Limestones (90 m, 64 m)
Maximum topographic relief	27 m	54 m	50 m

most difficult site to reach (no rail access). An advantage of the Cedar Creek Mine is the absence of any municipal or industrial water wells in the township (Ill. State Water Plan Task Force 1984; Shafer 1985). However, the Mississippian limestones underlying the mine area are exposed in lowland areas along the La Moine River and other nearby streams (Willman et al. 1967; Leary and Pfefferkorn 1977); any contaminants reaching the limestone formations would have a relatively short distance to travel before discharging to a surface stream or stream alluvium.

The Industry Mine is also located on a ridge, but topographic relief and potential erosion are somewhat less of a problem than at the Cedar Creek Mine. Like the Cedar Creek Mine, the Colchester No. 2 Coal is mined at this site; only about 30 m (100 ft) of Pennsylvanian strata occur beneath the mine pit. The overburden consists of hard shale and about 3 to 5 m (10 to 16 ft) of hard sandstone. When mined, these units form a coarse, bouldery spoil material that likely has high hydraulic conductivity. Less glacial till occurs at the Industry Mine than at the Rapatee Mine, which is disadvantageous for the Industry Mine. An advantage is that there are no large industrial or municipal water wells in the vicinity.

The Rapatee Mine appeared to be better suited for waste disposal than the other two mines for several reasons.

- About 70-75 m (230-245 ft) of Pennsylvanian shales, clays, siltstones, and thin limestones (i.e., low-permeability strata) occur beneath the mine floor.
- The overburden contains 5 to 8 m (15 to 25 ft) of clayey, silty glacial till and loess, which is advantageous for cap and liner construction.
- Some of the land was previously mined for an upper coal, and most of this land is little used.
- A rail line used for coal transport could also be used for transporting the Kerr-McGee wastes.

The disadvantages of the site include the presence of several towns about 2 to 5 km (1 to 3 mi) away (Rapatee, Middle Grove, Farmington) and their use of deep wells for water supply. However, these wells would not be affected by waste disposal because of their great depth and the thick layers of shale between the mine and the St. Peter Sandstone and other deep aquifers being used (see Section 4.6.2).

The Rapatee Mine was considered preferable to the other two mines primarily because (1) the Pleistocene deposits and Pennsylvanian strata are thicker and have low-permeability characteristics; (2) a larger flat upland is present, thus reducing the long-term erosion potential; and (3) a rail line for transporting wastes is available.

A.4 RECLAIMED SURFACE COAL MINE (ALTERNATIVE B)

A.4.1 Introduction

The total area of land in Illinois affected by surface coal mining through June 1983 was 906 km² (350 mi²), or 0.6% of the state (Ill. Dept. Mines Minerals 1985). These lands range from old abandoned sites, which were never graded (i.e., they still retain ridges of spoil material) and are partially or heavily overgrown with brush and trees, to more recently reclaimed areas, which have been covered with topsoil and brought back to productive farmland.

A.4.2 Potential Advantages of Alternative B

The advantages of developing a waste-disposal site in an older surface coal mine area are:

- Reclaimed surface coal mines occur throughout Illinois.
- Older mining sites are often unused and remote from populated areas.
- The older mine sites are usually not suitable for crop production because of poor soil conditions, stoniness, steep slopes, and erosion gullies.
- Older sites often have rail access.
- Coal extraction has been completed, so there should be no potential interference with current or future mining activities.

A.4.3 Potential Disadvantages of Alternative B

The disadvantages of using an older surface coal mine area are:

- The hydraulic conductivity of spoil materials often exceeds that of the undisturbed strata.

- The lakes and ponded water often present in surface-mined lands are frequently used for recreational boating, fishing, and swimming.
- Surface-mined lands are sometimes used for hiking and camping, and for state, county, and municipal parks.
- A waste-disposal facility may interfere with future recovery of additional coal reserves underneath or adjacent to the mine site.

With proper site selection, mined areas currently being used for recreation or homesites can be avoided. In addition, by choosing an old mine site where the overburden is composed of clayey tills, soft shales, and claystones, the concern about unacceptably high spoil permeability can be minimized. Finally, the site should be selected so that economically recoverable coal reserves underneath or adjacent to the proposed site are minimal or nonexistent.

A.4.4 Selection of a Reclaimed Surface Coal Mine

Nine general areas of past surface coal mining in northern Illinois were visited and evaluated as possible waste-disposal sites (Figure A.2). Mine areas in southern Illinois do not offer any additional geological/hydrological advantages but would have much higher transport costs for the wastes. As a consequence, these areas were not evaluated. General information for each of these areas is summarized in Table A.3.

Area No. 1. The general area closest to West Chicago is the Grundy-Will-Kankakee County mined area (Table A.3). This area has numerous small towns and sportsmen's clubs that use the mined areas for boating, fishing, swimming, and hiking. Because of the relatively high and widespread population density and heavy recreational use, the Grundy-Will-Kankakee County mined area was not considered further. This area was also dismissed because its spoil materials have relatively high hydraulic conductivity, and the water table is very close to the land surface throughout most of the area (Lindorff et al. 1981; Schubert 1984).

Area No. 2. The LaSalle County area (see Table A.3) has scattered patches of abandoned mines, mostly on bluffs above the Illinois River, where the topographic relief is high and the erosion potential is great. These abandoned areas are ungraded and usually very acidic and unvegetated (Bannister 1979; Harrison and Van Luik 1979; Lindorff et al. 1981). Several of the abandoned sites have been or are scheduled to be reclaimed using funds from the Illinois Abandoned Mined Lands Program. The Colchester No. 2 and underclay that were mined in this area rest directly on top of St. Peter

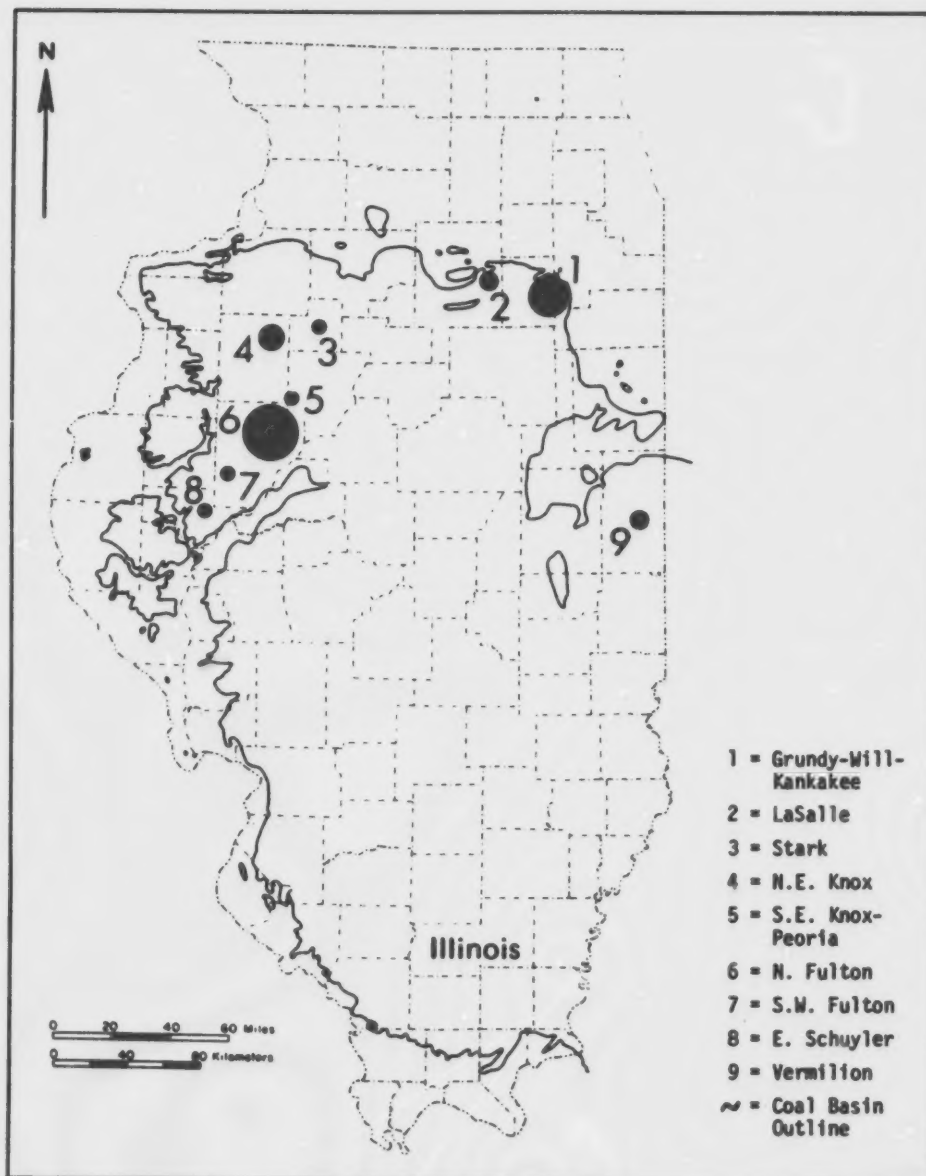


Figure A.2. Locations of the Evaluated Inactive Surface Coal Mine Areas (size of dots indicates relative amounts of surface-mined areas).

Table A.3. General Information for the Evaluated Inactive Surface Coal Mining Areas

Area No.	County	Nearby Towns	Disturbed Area through 6/83 (ha)	Reclaimed/Unreclaimed	Lakes	Topographic Relief	Land Use
1	Grundy, Will, and Kankakee	Morris, Wilmington, Braidwood, Coal City	6,383	Mostly ridge-and-swale topography; well vegetated	Abundant	Low	Numerous sporting clubs and homes
2	LaSalle	Ottawa	491	Mostly unreclaimed; acid spoils	Few	High	Generally unused
3	Stark	Modena, Wyoming	1,087	Mostly reclaimed; well vegetated	Abundant	Moderate	Grazing; some fishing and boating
4	N.E. Knox	Victoria	5,260	Some newer reclaimed areas, some older ridge-and-swale areas; mostly well vegetated	Abundant	Moderate	Sporting clubs; and possible state park; row crops and grazing
5	S.E. Knox and Peoria	Rapatee, Elmwood	7,360	Some graded and reclaimed, some ridge-and-swale areas; well vegetated	Abundant	Moderate to high	Grazing; sportsmen's clubs
6	N. Fulton	Middle Grove, Fairview, Canton, Cuba, St. David	17,680	Some graded and some ridge-and-swale areas; mostly vegetated	Abundant	Moderate to high	Sportsmen's clubs; grazing and some crop production
7	S.W. Fulton	Vermont, Astoria, Sumner	3,130	Mostly graded; well vegetated	Abundant	Moderate to high	Grazing and some crop production
8	E. Schuyler	Rushville, Pleasant View	900	Mostly ridge-and-swale topography; well vegetated	Abundant	Moderate	Sportsmen's clubs
9	Vermilion	Danville, Oakwood, Hegeler, Batestown	2,169	Mostly ridge-and-swale; moderately vegetated	Abundant	Moderate to high	Kickapoo State Park; sportsmen's clubs

Source: Data on disturbed areas from Illinois Department of Mines and Minerals (1985).

Sandstone, which is a major aquifer throughout most of northern Illinois. Lindorff et al. (1981) hypothesize that any water infiltrating into the mine spoils could percolate quickly downward into St. Peter Sandstone, which explains the general lack of a saturated zone at the base of the spoil materials. The combination of acidic spoil materials, high relief, high erosion potential, close proximity to an underlying aquifer of major importance, and close proximity to major towns and Starved Rock State Park makes this area a poor waste-disposal location. Thus, the LaSalle County area was excluded from further consideration.

Area No. 3. Stark County (see Table A.3) had one large strip mine (Allendale Mine) at its center. The mine is inactive and has been graded and reclaimed. Most of the mined areas are now flat grasslands used for grazing. The numerous final-cut lakes around the edges of the mined property are used for boating, fishing, swimming, and livestock watering. However, the area is very rural, so that the number of people using the mined area is small. During active mining, thick water-bearing lenses of sand and gravel were encountered in the glacial deposits, causing large water inflows into the active pits (Gilstrap 1985). Berg and Kempton (1984) mapped this area as having sand and gravel glacial deposits. The relatively high hydraulic conductivity of the spoil materials meant that the area was not investigated further.

Area No. 4. Northeastern Knox County near the town of Victoria has been extensively mined since the 1930s. Some areas of the MECCO Mine have undergone grading and soil reconstruction, and crop production on the reclaimed lands is now equal to that on adjacent undisturbed prime farmland. At other older mined areas (e.g., the Little John Mine area), the spoil materials, which were never graded, remain in a ridge-and-swale topography. The heavily wooded area contains many final-cut lakes and lakes lying between spoil ridges. The lakes and some of the land are used for recreation. There have been efforts by the county to have part of this mined land made into a state park, with development of extensive recreational facilities. Just south of the Little John Mine area is a large reservoir (Spoon Valley Lake), which receives drainage from much of the Little John Mine. New homes are being built near the lake. This mined area was eliminated from further consideration because of the extensive recreational use of the mined land, the state park that could be created, and the residential area around the large reservoir receiving drainage from the mined land.

Area No. 5. Southeastern Knox County and western Peoria County were mined by several different companies at different times. The areas in southeastern Knox County have undergone very little grading; they still have mostly ridge-and-swale topography with numerous final-pit lakes. The Elm Mine

and Edwards Mine areas in Peoria County have been more extensively graded. Most of the mined area has rolling topography, but many final-pit lakes are also present. There is at least one sportsmen's club in the area, and people use some of the lakes for boating, fishing, and swimming. There are also a few houses directly adjacent to the mined land. The western Peoria County area (Elm Mine) was chosen as the best disposal site within the reclaimed surface coal mine category. Thick, silty clay glacial materials were incorporated into the spoil materials; no sand and gravel lenses were encountered in the Pleistocene overburden; bedrock above the Herrin No. 6 Coal was primarily shale; and downward vertical migration of any leachates emanating from a waste-disposal cell would be prevented by the very thick (approximately 125-m) sequence of low-permeability Pennsylvanian shales, siltstones, sandstones, and thin limestones lying below the No. 6 Coal in this area (see Figure 4.15). Although there are several towns in western Peoria County, most of these are several kilometers distant from the mined land area under consideration.

Area No. 6. Northern Fulton County has by far the largest amount of mined land compared with the other areas being considered (see Table A.3). The mine sites were mined at several different times, using different mining practices and reclamation procedures. Almost all of these areas have abundant lakes, which occur in final cuts or between spoil ridges. At least one public park and several private clubs (e.g., Wee-Ma-Tak Country Club) are located partially or totally on mined land. The Buckheart No. 17 Mine southeast of Canton is inactive and currently undergoing final reclamation. Another large area of mined land west of Canton is being reclaimed by the Chicago Metropolitan Sanitary District (CMSD). It has been used for about 10 years for land spreading of sewage sludge and spray irrigation of sewage sludge decant water. CMSD plans to continue using the land for sludge disposal, crop production, and grazing. Northern Fulton County was given no further consideration because several towns are present in and around the mined areas, lakes are abundant everywhere in the mined areas, several parks and private sportsmen's clubs use the mined lands, and large areas are used for sewage sludge disposal and other commercial purposes.

Area No. 7. Southwestern Fulton County has had one large and several smaller surface mines in the past. AMAX Coal Company's Sun Spot Mine is the largest and most recent of these, but coal production was discontinued in the early 1980s. This mine site is in a relatively remote area; the largest towns, Vermont and Astoria, are several kilometers away from the mined areas. The Colchester No. 2 Coal was mined at this location, and only approximately 18 m (60 ft) of Pennsylvanian shales and sandstones lie between the No. 2 Coal and the Mississippian limestone aquifer below. Most of the mined land is located in the headwaters of Spoon River and Otter Creek. These streams and

their tributaries are incised relatively deeply into the landscape. Consequently, there is 20 to 40 m (65 to 130 ft) of topographic relief near some of the mine boundaries. The combination of thin Pennsylvanian strata beneath the No. 2 Coal and the deeply incised streams near the edges of the mined properties were the main reasons for excluding this area from further consideration.

Area No. 8. Eastern Schuyler County has several old surface-mined areas to the east and northeast of Rushville. These areas were surface and deep mined by several small coal companies in the 1930s and 1940s, primarily for the Springfield No. 5 Coal. In 1958-1966, Peabody Coal Company operated the Key Mine, whose workings went through and around many of the previous mines. The area is characterized by very hilly ridge-and-swale topography, with lakes present in all of the final cuts and in low areas between spoil ridges. There is some evidence of recreational use of the lakes in this area. However, use of this land may be very limited because the area is fairly remote. The long transport distance to this site from West Chicago, the difficulties of access, and the presence of numerous abandoned underground workings (many of unknown extent) are the reasons for not considering this area further.

Area No. 9. Large land areas have been surface mined in Vermilion County in eastern Illinois; however, several reasons make this area unattractive as a potential disposal site for the Kerr-McGee wastes: (1) the mines are located around the city of Danville and numerous other small towns; (2) much of the mined area has been incorporated into Kickapoo State Park, which is used extensively for swimming, fishing, boating, and hiking; and (3) two major streams (the Salt Fork and Middle Fork of the Vermilion River) flow through or directly adjacent to most of the mined areas.

A.5 UNDERGROUND COAL MINE (ALTERNATIVE C)

A.5.1 Introduction

Huge volumes of underground space have been created in the Illinois Coal Basin by past underground mining operations. Many of the mines have been abandoned and sealed and are no longer accessible. Even in the active underground mines in Illinois (31 operating in 1984), many of the worked-out panels have been sealed with bulkheads, and it would be difficult, costly, and perhaps dangerous to reopen these panels. Water and methane gas can accumulate in sealed panels. In addition, the roof supports and roofs usually deteriorate over time in the older mined sections.

If an underground coal mine were used to dispose of the Kerr-McGee wastes, the best approach would be to obtain ownership of an active mine at the point when coal extraction is finished and there is no more economically recoverable coal in the immediate vicinity of the mine. The facilities and

equipment that had been used to mine the coal could then be used for the waste-disposal operation. After the wastes were in place, the mine would be tightly backfilled in the immediate vicinity of the wastes with low-permeability materials, the panel(s) used for waste disposal would then be sealed with bulkheads, and the mine entrances would be filled and sealed according to state and federal regulations (e.g., see 30 CFR Part 817).

In a conventional room-and-pillar type mine, the panel(s) used for waste disposal would probably be the one(s) mined just before mining was finished. The panel(s) could possibly be designed specifically for waste emplacement and containment.

A.5.2 Potential Advantages of Alternative C

The advantages of using an existing underground coal mine are:

- Illinois underground coal mines are usually 46 to 274 m (150 to 900 ft) deep (Treworgy and Bargh 1982) and are accessed by vertical shafts and angled slopes. (Few active mines, if any, have horizontal drifts.) Emplacement of wastes at these depths would put them far below the effects of animal burrows, tree roots, erosion, and human surface activities. Also, the rate of radon emission would be infinitely small.
- The underclay beneath the mined coal and the shales, siltstones, and thin limestones above the mined coal generally have very low values of hydraulic conductivity. Many Illinois underground coal mines experience a very low rate of groundwater inflow during active mining operations.
- After the wastes had been placed in the mine and proper backfilling and sealing had occurred, groundwater would slowly seep into the mine, not out. It might take hundreds of years for a mine cavity to resaturate and for the hydrostatic pressure to reach approximate conditions that existed before mining. At that point, groundwater flow into or out of the mine might be negligible because the hydraulic gradients and hydraulic conductivities of coal-bearing rocks at that depth would be extremely small.
- The underclays typically found beneath a coal seam and the black and gray shales usually found above a coal seam are composed primarily of different mixtures of kaolinite, illite, and illite-montmorillonite (mixed-layer) clays (Gluskoter 1967; Rao and Gluskoter 1973). These thick deposits of clayey materials have moderate to high adsorption and

ion-exchange capacities. If contaminants from the wastes were to migrate from the mine cavity, most of them would be adsorbed onto the clays.

- Coal has some ion-exchange and adsorption capabilities (Reese and Lovell 1965) and could therefore restrict the lateral movement of many contaminants through any remaining coal beds.
- Placing the wastes deep underground should not affect future land use at the surface. Surface activities should not interfere with isolation of the wastes. The surface land could be used for agriculture or other uses, thus preserving to some extent the surface land values.
- An advantage of an existing underground mine is that excavation has already taken place and that buildings, hoists, ventilation systems, communication systems, and other appurtenances are already in place and operational. Subject to compensation being made to the owner of the mine, these structures and equipment could be left in place for use in the burial of the Kerr-McGee wastes. Because most underground coal mines have a rail spur, rail transportation for the wastes would likely be available.
- Personnel formerly employed by the coal company might be available for employment and would be experienced in mining operations, mine repairs, underground materials handling, underground sealing techniques, and many other necessary engineering activities. Therefore, it might not be necessary to hire an entirely new work force.

A.5.3 Potential Disadvantages of Alternative C

There are several possible disadvantages in using an underground coal mine for disposal of the Kerr-McGee wastes.

- Because the wastes would be buried at depths greater than 50 m (165 ft), the passageways would be sealed, and the mine entrances would be completely backfilled and sealed, it would be very impractical, very costly, and technically difficult to reenter the disposal cell and retrieve the wastes if any problems arose.
- Roof failure and subsidence in the disposal cell or in surrounding mine panels could create vertical fractures or open existing joints, thus providing pathways for leachate migration.

- Coal seams in most Illinois underground mines are about 2 to 3 m (6 to 10 ft) thick, which would restrict the size of the waste materials or waste containers that could be transported within the mines.

A.5.4 Selection of an Underground Coal Mine

Eight active underground coal mines were investigated. Figure A.3 shows the location of each coal mine, and Table A.4 gives general information about the mines. Two of the mines (Peabody No. 10 and Murdock) were opened before 1970, three were opened in the 1970s, and three have been opened since 1980. Seven of the eight mines are located north of 39° latitude. Kerr-McGee Coal Corporation's Galatia Mine in Saline County in southern Illinois was also visited and evaluated.

Room-and-pillar mining techniques and continuous miners are being used at all of these mines. The Ziegler No. 5 and Murdock mines are the shallowest, and the Galatia Mine is the deepest. The mines are operating in a single seam, with the exception of the Galatia Mine, which is the only underground mine in Illinois that operates in two seams. Most of the areas are very dry during active mining, and very little water leaks into the mines. Minor amounts of water sometimes accumulate in sealed panels.

The Galatia Mine was eliminated from further consideration because it had just begun operation in 1983 and only small areas had been mined out. The coal company plans to operate the mine for at least 20 more years. There are many safety and logistical reasons why coal mining and waste disposal could not take place simultaneously in an underground mine, albeit in different sections. The Galatia Mine is also an inappropriate candidate because mining is occurring on two different levels. If, for some unforeseen reason, the containment cell were to leak after the mine had been closed and sealed, the contaminants would have two geologic horizons as potential migration paths.

All of the mines, with the exception of Ziegler Coal Company's No. 5 and Murdock mines, were eliminated from consideration because they are expected to be active for at least 20 more years. As stated above, numerous problems could be anticipated if coal were mined and wastes were disposed of simultaneously in the same mine.

Ziegler Coal Company's Murdock and No. 5 mines are adjacent to each other near the town of Murdock in Douglas County. The Herrin No. 6 Coal is being mined, and the same methods and machinery are being used. Ziegler Coal Company anticipates that both of these mines will be operated for 5 to 10 more years. Because the Murdock Mine is older and its remaining coal reserves are somewhat smaller, its life expectancy is shorter than that of the No. 5 Mine. In addition, the Murdock Mine has less groundwater inflow and a harder,

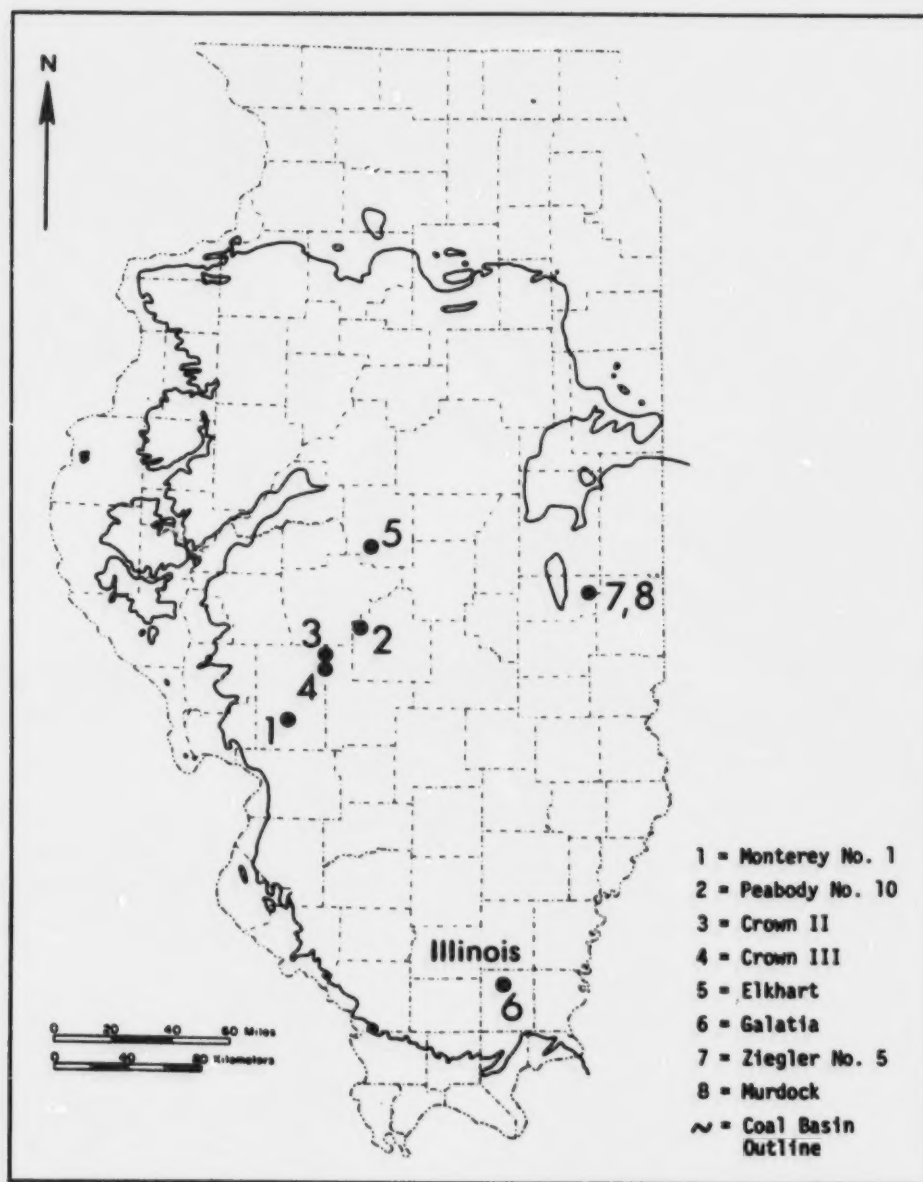


Figure A.3. Locations of the Evaluated Active Underground Coal Mines.

Table A.4. General Characteristics of the Evaluated Underground Coal Mines^a

Area No.	Name	County	Coal Seam(s) Mined	Depth at Portal (m)	Year Opened
1	Monterey No. 1	Macoupin	No. 6		1970
2	Peabody No. 10	Christian	No. 6	104	1952
3	Crown II	Macoupin	No. 6	99	1976
4	Crown III	Macoupin	No. 6	117	1981
5	Elkhart	Logan	No. 5	91	1982
6	Galatia	Saline	Nos. 5 and 6	167 (No. 5)	1983
7	Ziegler No. 5	Douglas	No. 6	61	1973
8	Murdock	Douglas	No. 6	61	1946

^a Room-and-pillar mining techniques and continuous mining equipment are used in all the mines.

more stable underclay in the floor than at the No. 5 Mine. The Murdock Mine is also farther downdip along the axis of the Murdock syncline, which plunges south-southwest, so waste disposal could take place in the structurally lowest part of the mine complex. This location would also be at the greatest depth below the surface, and the mine has the least potential for contaminant migration. For these reasons, the Murdock Mine was chosen as the best potential active underground coal mine.

A.6 FARMLAND SITE (ALTERNATIVE D)

A.6.1 Introduction

There are vast areas of farmland in Illinois, some of which is little used. Farmland is generally located away from urbanized areas, and municipal landfills and hazardous waste facilities are usually sited on farmland or unused land. Agricultural land in Illinois exhibits a tremendous range of geological and hydrological characteristics. The criteria most important for selecting a site for disposal of the Kerr-McGee wastes include (1) low-permeability geologic materials underlying the site and available for cover material; (2) sufficient distance from populated areas; (3) sufficient horizontal distance from streams and vertical distance above groundwater aquifers; (4) sufficient distance from important cultural or natural features, such as parks; and (5) site accessibility, either by an acceptable highway route or rail line.

A.6.2 Potential Advantages of Alternative D

The principal advantages in using a farmland site are (1) the chosen site can be flat and have low-permeability soil and subsoil materials and (2) the site can be close to West Chicago to minimize transportation risks and costs.

A.6.3 Potential Disadvantages of Alternative D

A disadvantage is that most farmland is being actively used and, therefore, locating unused land with all the necessary characteristics could prove extremely difficult. Hence, the purchase of currently used farmland would likely be necessary, which would take land out of agricultural production. However, this impact would be very small because the land chosen would be an insignificant small percentage of the available farmland in the state.

A.6.4 Selection of a General Area

The farmland site was to be located in northeastern Illinois to minimize transportation costs and associated accident risks; however, no areas in Cook, Lake, DuPage, or Will counties were considered because of their high population densities. The starting point for selecting a farmland area was the ISGS map of Berg and Kempton (1984), which classifies land areas in the state as to their risk potential for shallow groundwater contamination resulting from land burial of municipal wastes. Areas on the map designated D, E, F, or G have the lowest potential risk and may contain good sites for waste repositories. Only these areas were considered further.

Additional references were consulted regarding the stratigraphy and particle-size analyses and permeabilities of glacial tills in northeastern Illinois (Wascher et al. 1960; Thornburn et al. 1966; Willman and Frye 1970; Landon and Kempton 1971; Alexander and Paschke 1972; Paschke 1978; Goddard 1979; Lineback 1979; Reineback 1980; Killey 1980, 1982; Kempton et al. 1985). The Wadsworth and Yorkville till members seemed to have the highest percentage of silt and clay. In addition, surface soils developed on these tills were usually rated in the county soil reports as being slowly to poorly drained, thus indicating relatively low hydraulic conductivity for the unweathered parent materials (i.e., surface tills and loess). Because the Wadsworth Till Member is found almost exclusively in Cook, Lake, DuPage, and Will counties, the Yorkville Till, which has a greater geographic distribution, was selected as the surface till unit most preferred for a waste-disposal site.

The uppermost bedrock units of a good potential disposal site should also have low hydraulic conductivity. The two northern Illinois rock units that have the lowest hydraulic conductivities, are used the least as a source of

groundwater, and are present as the uppermost bedrock units over significant areas are the Pennsylvanian rocks and the Ordovician Maquoketa Group.

The upper dolomites of the Maquoketa Group are often permeable and hydraulically part of the Silurian dolomite aquifer. The Pennsylvanian System rocks can attain much greater thicknesses than those of the Maquoketa Group. Therefore, thick Pennsylvanian strata were chosen as the preferred upper bedrock site condition.

After considering the available published literature, an area located southwest of Chicago and south of the Illinois River was selected for further investigation (see Figure 4.23) because Pennsylvanian strata are much thinner or absent north of the Illinois River. The selected area generally has thick layers of clayey Yorkville Till overlying a thick sequence of low-permeability Pennsylvanian strata. Its southern half is also classified as having low potential for contamination of shallow groundwater (Berg and Kempton 1984).

The general farmland area (southern half of Figure 4.23) includes the southern half of Grundy County, the southeastern corner of LaSalle County, and the northeastern corner of Livingston County. To reduce the large general area to a smaller specific site, published information on the area geology and hydrology was evaluated in more detail, drill hole data were collected and evaluated, and the area population distribution was qualitatively evaluated.

Berg and Kempton (1984) state that their map is designed for regional evaluations only and is based on the probabilities of finding a site with good or poor conditions for waste disposal. Therefore, further evaluation was necessary to verify the suitability of the area for disposal of the Kerr-McGee wastes.

A.6.5 Selection of a Specific Area

A detailed study of surficial Pleistocene deposits in this area had been conducted by ISGS (Killey 1982); this information is summarized in Chapter 4, Section 4.6.5. The Yorkville Till Member (and the Dwight mineralogical zone therein) is a very fine-grained material (40-60% clay, 30-50% silt, 0-15% sand). The till is about 27 m (90 ft) thick in borehole LaS 40 and may be even thicker to the south along the crest of the Ransom moraine (see Figure 4.24). The Yorkville Till is generally thinner in areas away from the moraines. A disposal site on the crest of the Ransom moraine would have two advantages: (1) the Yorkville Till would have its greatest thickness, especially to the south, and (2) the disposal site would be sufficiently far from any surface streams. The morainal crest is very broad, with very gentle slopes, so severe erosion should not occur. Farmhouses appear to be very sparse in most areas along the morainal crest.

The Pleistocene deposits rest on an erosional surface developed in the Pennsylvanian strata. Bedrock highs seem to generally coincide with the crests of the Ransom and Minooka moraines (Killey 1980). Along the crest of the Ransom moraine south of the Illinois River, the bedrock surface ranges from about 122 to 198 m (400 to 650 ft).

The major structural feature in the area is the series of northwest-southeast-trending anticlines and synclines that form the LaSalle anticlinal belt (Figure A.4). This broad upwarp extends southeastward through most of Illinois.

The Jacobson (1985) study of the coal geology and resources in this area provides detailed information on the depths, distribution, and thicknesses of individual coal seams; the thicknesses of strata between individual coal seams; the structural contours on individual coal seams; the mined-out areas of each coal seam; and the recoverability of remaining coal deposits. A structural contour map of the Colchester No. 2 Coal shows that there are local domes and depressions in the coal elevational surface, but that overall the coal dips to the west and southwest (Jacobson 1985--Plate 6). Subtracting the structural elevation of the Colchester No. 2 Coal from the surface elevation of the area results in a map showing the depth to the Colchester No. 2 Coal (Figure A.5). Because the No. 2 Coal is within about 6 to 24 m (20 to 80 ft) of the base of the Pennsylvanian System (Jacobson 1985), Figure A.5 approximately represents the combined thickness of the Pennsylvanian and Pleistocene deposits. The greatest depth to the No. 2 Coal is toward the western, southwestern, and southern edges of Figure A.5. If the general area map (Figure 4.23) is superimposed over the depth-of-No.-2-Coal map, and if the domain of interest is restricted to the Yorkville Till area and the crest of the Ransom moraine, then the thickest sequence of materials is the shaded area lying primarily in SE1/4, T30N, R5E (see Figure A.5). According to this map, the depth to the No. 2 Coal is greater than or equal to 122 m (400 ft). Figure 4.25 shows a cross section of Pennsylvanian strata in the area, and one geophysical record (Hole No. 6, T30N, R5E) shows about 24 m (80 ft) of Pennsylvanian strata beneath the No. 2 Coal. Thus, there is altogether about 150 m (500 ft) of Pennsylvanian and Pleistocene deposits in the vicinity of the borehole.

At the base of the Pennsylvanian System is an erosional unconformity. The age and type of rocks that underlie the Pennsylvanian System in northern Illinois are quite variable. Where the Silurian dolomites have been eroded away, the Maquoketa Group directly underlies Pennsylvanian System rocks. Thus, the two low-permeability rock units are in contact over a semicircular area that extends from eastern Grundy County, along the northern edge of

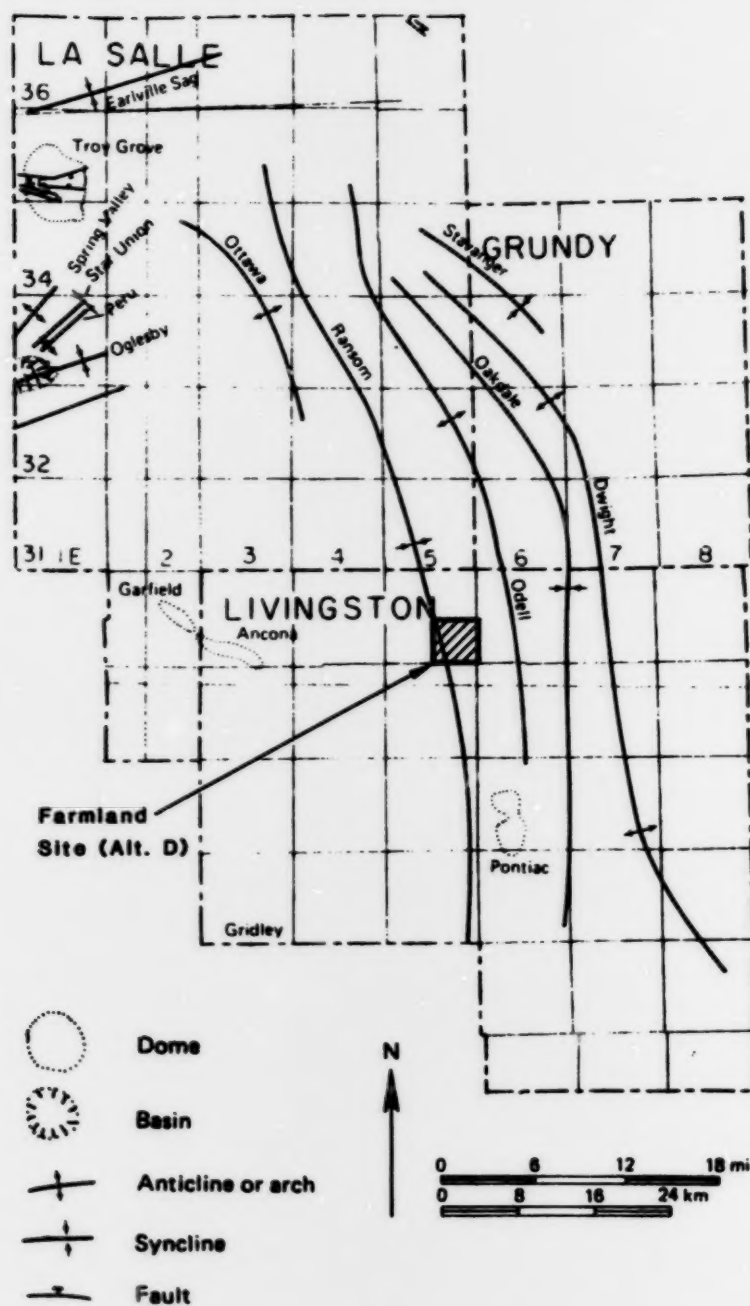


Figure A.4. Structural Geologic Features of the Farmland Site and Vicinity.

Source: Modified from Jacobson (1985).

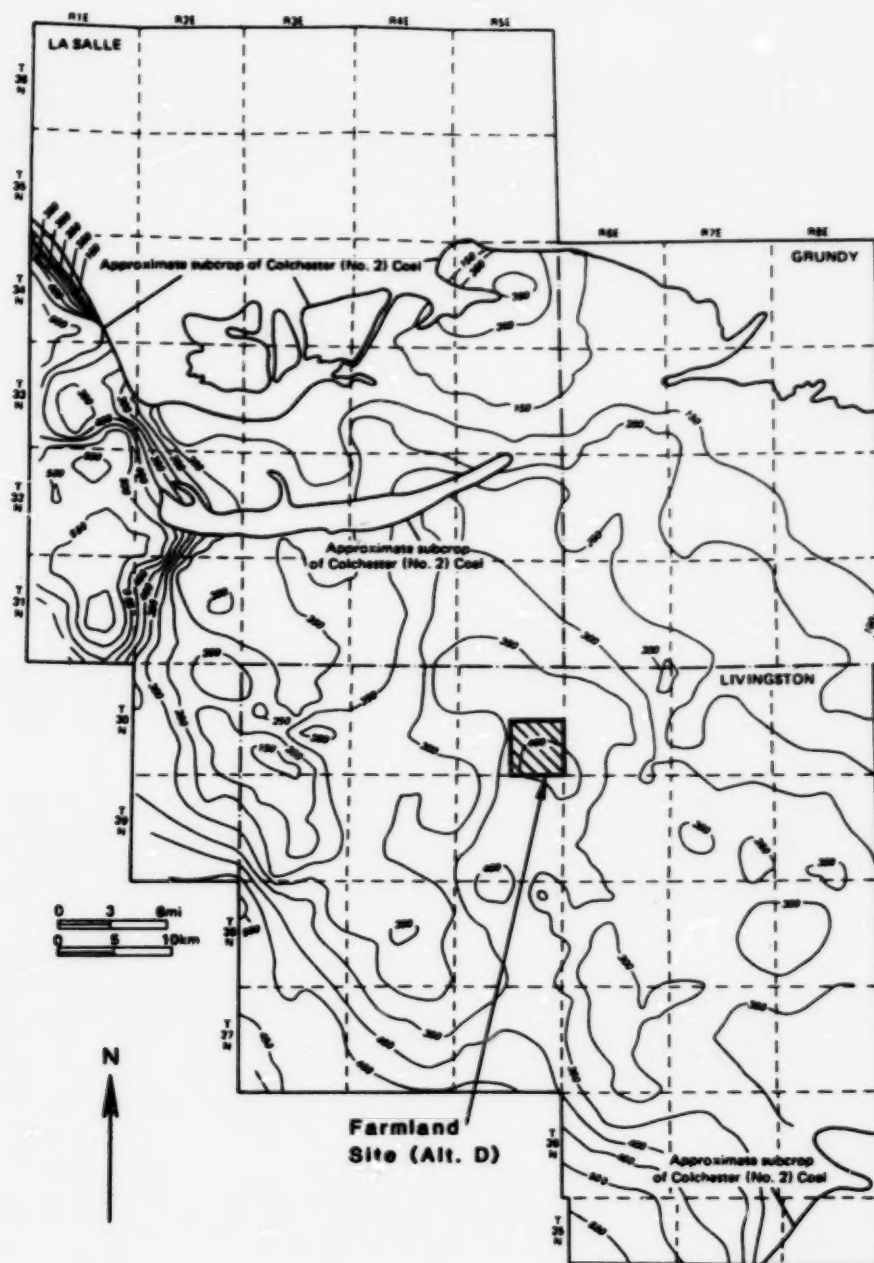


Figure A.5. Depth (in feet) of the Colchester No. 2 Coal at the Farmland Site and Vicinity.

Source: Modified from Jacobson (1985).

Livingston County, and northwestward through parts of LaSalle County (Figure A.6). This area also intersects the area of thick Pennsylvanian strata and thick, clayey Pleistocene deposits in T30N, R5E. Therefore, a sequence of three thick, low-permeability geologic units occurs near the surface at the farmland site (see Figure 4.27). At this location, as much as 168 m (550 ft) of low-permeability materials occurs above the first major bedrock aquifer -- the Ordovician Galena and Platteville dolomites.

On the basis of the information presented in this section, the best location is SE1/4, T30N, R5E. However, before the site was selected for inclusion in the alternative sites analysis, other pieces of information were collected and evaluated. First, ISGS drill log files showed that very few shallow water wells had been drilled in the designated area. Second, the few residential water wells that had been drilled in and around the area encountered only very few thin, muddy sand and gravel layers within the till. No major water-producing zones were found. According to ISGS maps (Damberger et al. 1984; Jacobson 1985), no surface or underground mining has occurred within about 10 km (6 mi) of the farmland site. Finally, the potential recoverability of any coal seam in T30N, R5E, has been estimated to be very low (Treworgy and Bargh 1982; Jacobson 1985); therefore, potential conflicts between a waste-disposal site and mining operations should not arise.

A.7 CLAY AND SHALE SURFACE MINES

A.7.1 Introduction

Clay and shale surface mines were previously advocated by Kerr-McGee (1980) as a potential alternative disposal category. Twenty-one clay and shale mines were visited and evaluated by Kerr-McGee and one site (Site No. 3 in northwestern Bond County) was eventually chosen as the most favorable. However, the site's geology and hydrology were not evaluated in detail. For the analysis in this Supplemental Environmental Statement, reclaimed clay and shale surface mines were ranked as the best potential category (1.55) during the category selection process (see Section A.1). Thus, the desirability of using a clay or shale surface mine was reaffirmed.

In general, three types of clay or shale have been mined in Illinois. The most extensively mined deposits are the shales and underclays associated with Pennsylvanian coals, particularly those at or near the base of the Pennsylvanian System. The second type is Cretaceous and Tertiary embayment deposits at the southern tip of Illinois. The third type is clay and silt deposited in large ice-dammed or moraine-dammed Pleistocene lakes. These deposits differ as to the nature and extent of the deposit; in addition, clay mineral composition and purity can be highly variable.

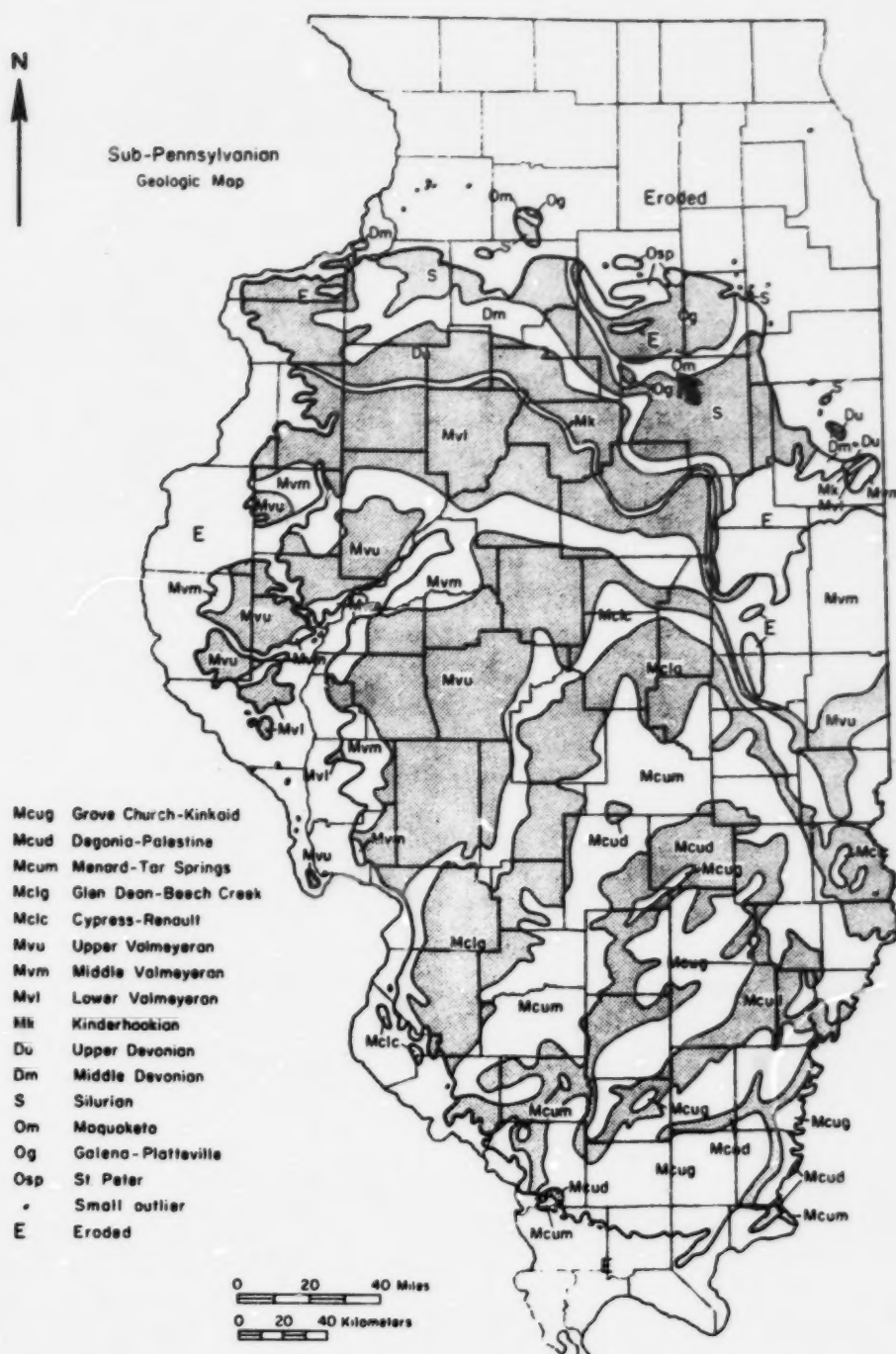


Figure A.6. Geologic Map of the Illinois Sub-Pennsylvanian Bedrock (arrow points to the Alternative D Site).

Source: Modified from Willman et al. (1967).

A.7.2 Potential Advantages of Using a Surface Clay or Shale Mine

- If a shale or clay deposit is thick and extensive, then the materials surrounding and underlying the mine site should have relatively low hydraulic conductivity and relatively high adsorption capability. These characteristics are desirable for a waste-disposal site.
- Because the mine pit would already have been excavated, some earth-moving costs would be saved. However, some additional excavation would be needed to ready the pit for disposal operations and to obtain and stockpile additional material for constructing the disposal cell cap.
- Clay and shale mine sites are seldom used for other purposes and have little value following mining operations. Therefore, using a mine site for waste disposal would not create a situation where valuable land would be devalued.

A.7.3 Potential Disadvantages of Using a Surface Clay or Shale Mine

- Surface clay or shale mines might be too small, and significant additional excavation work might be required to enlarge the pit for construction of a below-grade disposal cell.
- If the clay or shale deposit were thin, then the mining operation might have removed the entire thickness. The geologic and hydraulic properties of the strata underlying and surrounding the mine pit would have to be characterized to ensure that low-permeability materials were present.
- Mined Pennsylvanian shales usually have a high clay content, which means that their hydraulic conductivities as undisturbed rock are usually quite low. However, when shale is excavated and moved, the resulting material may be boulder- and gravel-sized rubble having very high hydraulic conductivity. The value will depend on the hardness and the slaking and physical-weathering characteristics of the shale fragments. Shale may be an excellent geologic medium for waste disposal, but it may be completely unsuitable as a low-permeability cap material.

A.7.4 Clay and Shale Mines That Were Evaluated

Figure A.7 is a map of the 24 clay and shale mines identified by Kerr-McGee (1980) as possible waste-disposal sites. During the summer and fall of

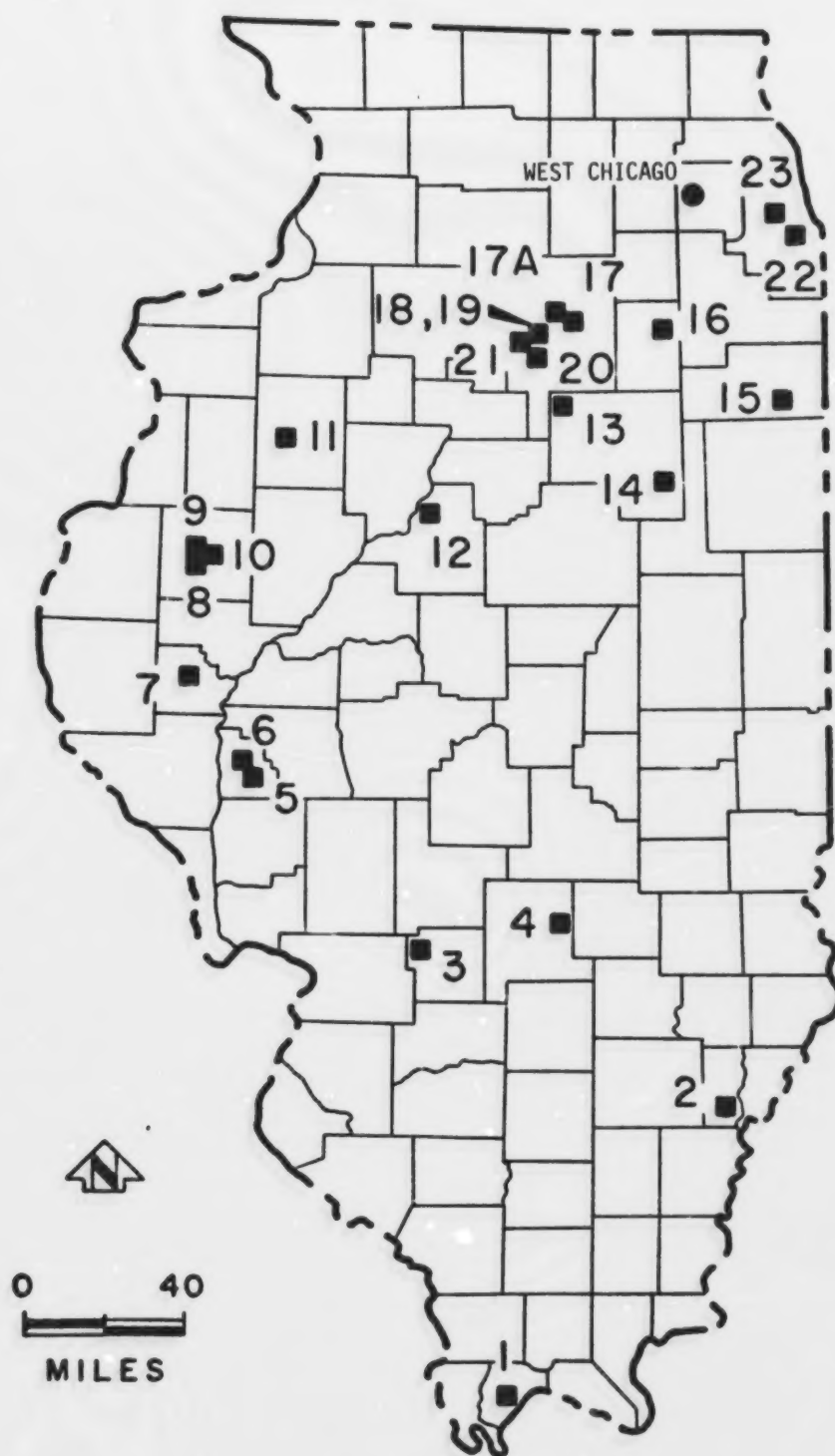


Figure A.7. Location of the Candidate Clay and Shale Surface Mines.
Source: Kerr-McGee (1960).

1985, 17 of the 24 clay and shale mines were visited and evaluated by the staff. Included in the group of 17 sites were the six sites that had been selected by Kerr-McGee as the best candidates. The sites are described and evaluated, in numerical order (Figure A.7), in the following subsections.

Site No. 3. Site No. 3 is the Richard Brick Company shale mine (Figure A.8), located in northeastern Bond County about 4 km (2.5 mi) southwest of Sorento (NW1/4, Sec. 13, T6N, R5W). Near-surface Pennsylvanian shale was excavated at this mine, which was designated as the best alternative disposal site by Kerr-McGee (1980). The following observations were made by the staff during two site visits:

- The area immediately around the mine site is flat, with minor topographic relief.
- The abandoned shale pit is filled with 1 to 2 m (3 to 6 ft) of water, is irregular in shape, and covers an area of about 14 to 20 ha (35 to 50 acres).
- The pit floor is about 5 to 7 m (15 to 22 ft) below the surrounding land surface.
- The pit sidewalls slope at about 45°; the pit floor is relatively flat, except for small islands of mine spoil materials in the pit floor lake.
- On the south side of the pit area, two or more intermittent stream channels lead directly into the pit area.
- Two farmhouses are located directly adjacent to the site, one of which has a lake impoundment adjacent to the mine pit.

During the first visit to the site, the gate entrance was locked and posted, and the site appeared to be abandoned. However, during the second visit, dump trucks loaded with shale were being driven down a haul road through the abandoned pit area, and shale was being loaded into a string of hopper cars on a railroad siding immediately north of the site. According to the employees, the shale pit next to the road was abandoned in 1981, but a new pit was opened about 1.6 km (1 mi) to the south. The new mine occupies about 32 ha (80 acres), but only 0.4 ha (1 acre) is disturbed annually. The haul road through the abandoned pit and the railroad siding were still being used for transport of the shale from the new mine site.

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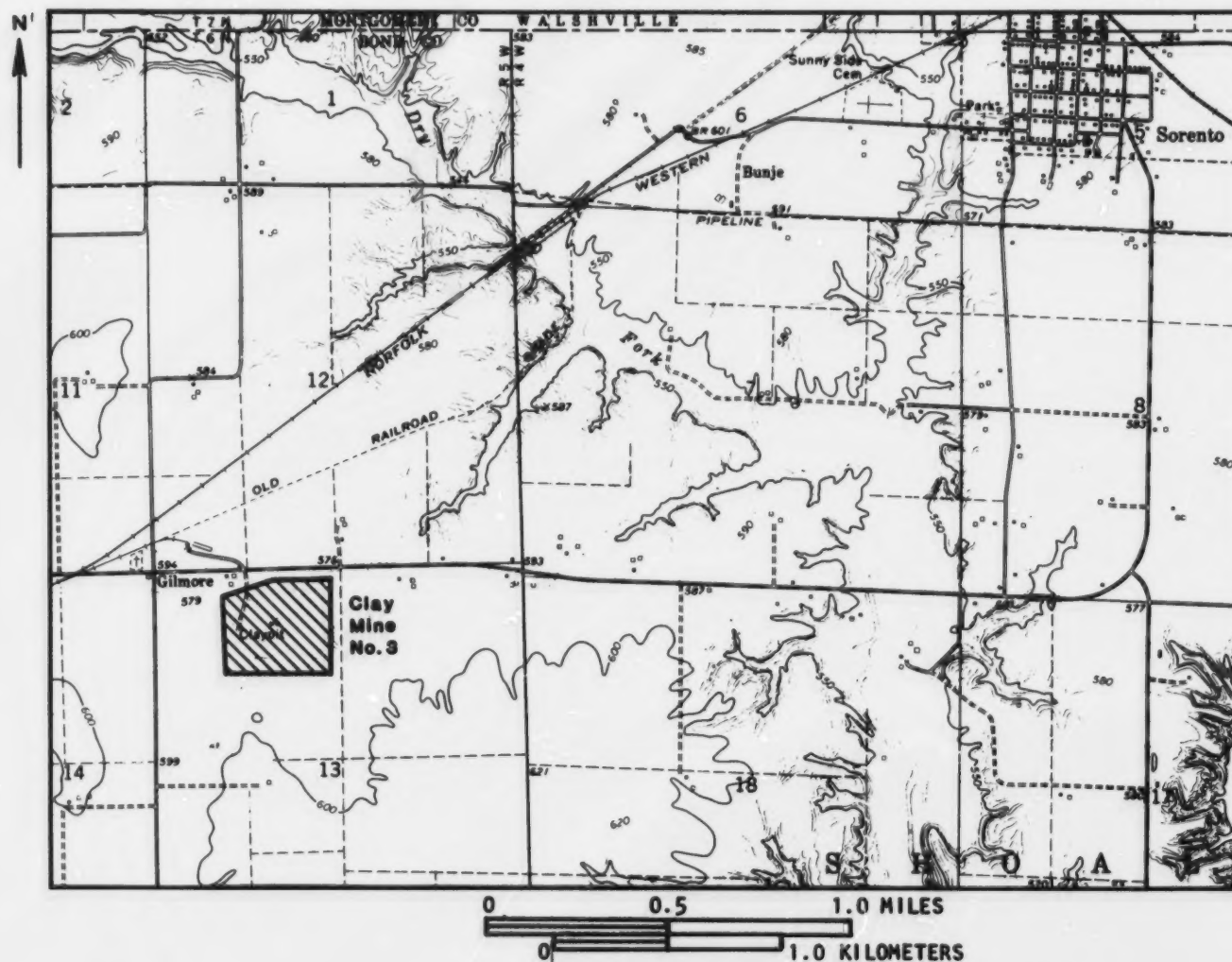


Figure A.8. Topographic Map of Clay Mine No. 3 and Vicinity.
 Base Map: U.S. Geological Survey, Sorento South
 7.5-Minute Quadrangle (1974). 322

Site No. 3 was not considered further because of the stream channels leading directly into the pit area, the two houses and reservoir directly adjacent to the site, and the potential interferences with a long-term mining operation.

Site No. 5. Site No. 5 is an abandoned shale mine located about 2 km (1 mi) northeast of the town of Alsey in Scott County (see FES--Fig. 4.7). It was previously operated by the Alsey Refractories Company but was closed about 25 to 30 years ago. The mine is a contour strip mine, extending north-south along the base of a hillslope. The exposed highwall is about 5 to 7 m (16 to 23 ft) high; the ponds in the mine pit that cover the remainder of the highwall may be deep. On the east side of the strip mine is a wooded uphill slope. A large ridge of acidic-looking spoil material lies on the low wall (west side) of the mine. An unnamed tributary to Little Sandy Creek flows northward directly past the outer toe (west side) of the spoil material.

This site was visited in September 1985. Despite the very dry weather, the tributary to Little Sandy Creek was flowing and appeared to be a perennial stream. The ponds in the mine pit are used by some local residents for swimming. One person swimming at the mine stated that an original road to the mine had a bridge crossing the stream; however, a large rainstorm and the subsequent stormflow in the stream completely washed out the bridge one or two years ago. Therefore, the stream is probably capable of high flow rates and severe bank erosion.

Near the center of the strip mine was the abandoned slope entrance to an underground mine. The swimmer claimed that his grandfather had worked in the underground coal mine a long time ago. A map of abandoned coal mines in this area shows an abandoned underground mine entrance at this location (Nawrot et al. 1982). However, the depth and extent of the mine workings are unknown.

Using this mine for a waste-disposal site would be ill-advised because of the flooded condition of the strip mine, the steep surface slopes in the area, the underground mine workings beneath the strip mine, the flood-prone stream directly adjacent to the mine, the extremely poor condition of the access road, and the lack of a bridge over the stream.

Site No. 6. The mine at Site No. 6 is a very small strip mine located on the side of a south-facing hillslope about 4.5 km (2.8 mi) northeast of Exeter in Scott County. It consists of two small hillside pits extending east-west about 30 to 120 m (100 to 400 ft) from a north-south paved county road. The two pits cover an area of about 0.5 ha (1.2 acres), have a highwall about 5 to 12 m (15 to 40 ft) high, and contain about 1 to 3 m (3 to 10 ft) of water. Pennsylvanian shale was mined at this site. The general area slopes (steeply in some places) toward Mauvaise Terre Creek, which is a short distance south

of the mine site. This site is unsuitable for waste disposal because of the small capacity of the shale pits, the steeply sloping site conditions, and the difficult access to the site.

Site No. 7. The Site No. 7 mine, which consists of two abandoned hillside quarries in Pennsylvanian shale, is located about 5 km (3 mi) southwest of Mt. Sterling in Brown County. It had been operated by Diller Tile Company but, according to an employee at the office in town, was abandoned many years ago. Both of these pits are small, having highwalls approximately 8 m (26 ft) high. Three sides of each pit are open, and the pit floor is approximately level with the road and slightly above a small stream directly adjacent to the excavated hillsides. There are no below-grade pits in which to bury wastes. This site was eliminated because of steep slopes (high erosion potential), the lack of a subgrade excavated pit, the difficult access, and the very close proximity of a stream.

Site No. 9. Site No. 9 consists of two separate, deeply incised valleys that have been strip-mined for Pennsylvanian clay and possibly coal (see FES--Fig. 4.8). The first abandoned quarry observed was located east of County Road 11 across from the McClure limestone quarry. It is approximately 2 km (1.2 mi) north of Tennessee, 3.5 km (2.2 mi) northwest of Colchester, and 4 km (2.5 mi) southwest of Argyle Lake State Park. The second abandoned strip mine is located about 1 km (0.6 mi) farther east. Both of these mines are situated near the upper ends of valleys that are tributary to the East Fork of the La Moine River, about 400-600 m (1,300-2,000 ft) southeast. The mine shapes are irregular and mimic somewhat the shape of the original valleys. Although no water was observed flowing through these upland valleys, water flow during and after storms may be intense, and the erosion potential appeared to be great.

Two large operating limestone quarries are located near the shale mines; Mississippian St. Genevieve or St. Louis limestones are being quarried for use as crushed stone. These limestones form a major bedrock aquifer. At the McClure limestone quarry, the following strata (in ascending order above the limestone) were observed in the highwall as seen from inside the pit: 2 m (7 ft) of weathered shale or underclay; about 30 cm (10 in.) of pyritic coal; 3 to 4 m (10 to 13 ft) of soft gray shale; 2 to 3 m (7 to 10 ft) of channel sandstone; and 2 to 3 m (7 to 10 ft) of brown, oxidized till and loess. An employee stated that the surface mine operation occasionally intercepts very old underground mine workings in the clay just above the limestone. This clay is the one observed nearby at Site No. 9.

Site No. 9 was excluded from further consideration because of the deeply incised valleys, which create flooding and erosion potential; its close proximity to a major stream; its close proximity to two active limestone

quarries; and a major aquifer (the Mississippian limestones) lying directly below the clay. Sites Nos. 8 and 10 were supposedly located close to No. 9, but could not be found. Local residents said that these clay mines were also located close to the banks of the East Fork of the La Moine River. Because these sites would be subject to the same geohydrological limitations as Site No. 9, they were also excluded.

Site No. 11. At Site No. 11, the Galesburg Brick Company previously operated a clay mine and brickworks in East Galesburg, east of County Route 9, in Knox County. This entire operation has been abandoned, and the numerous buildings, warehouses, and kilns are crumbling and the area is heavily overgrown with brush. The size and number of the buildings and kilns indicate that this operation must have been very large. The clay mine appears to be a large, vegetated, bowl-shaped valley, surrounded on the east, west, and south by steep valley walls. Residential areas were observed on the upland above the west side of the valley. The valley floor has some areas of clay spoil piles, many ponds in depressions, one old haul road running down the center, and a large area of wetlands on the east side. Along the west side of the valley, a typical strip mine appearance was observed; that is, Pennsylvanian shale and clay were exposed in vertical highwalls. Because of the large size of the former brick-making operation, it was impossible to determine how much of the valley was there initially and how much valley floor had been created by mining.

Site No. 11 was excluded from further consideration because of the large size of the valley, the extensive ponds and wetlands in the valley floor, and the close proximity of houses on the west side of the valley. Also, it was not known whether a stream flows through this mined-out valley and what flow conditions could be expected.

Site No. 13. Site No. 13 is located southwest of Streator in Livingston County. Streator Brick Systems previously operated a shale quarry at the site, directly behind its brickyard. However, that pit was closed at least 10 years ago and a new pit was opened about 0.5 km (0.3 mi) southwest of the city. Pennsylvanian shales are extracted from the active surface mine. A dozer scrapes off the unconsolidated glacial materials (<3 m thick), and a small dragline excavates the rock. The active pit is about 100 m (300 ft) long, 10 m (30 ft) wide, and 10 m (30 ft) deep. About 5 m (15 ft) of shale is extracted from the lower part of the pit. The upper bedrock, which grades into siltstone and fine-grained sandstone, is unusable and is backfilled with the glacial materials into the previous mine strip. The Vermillion River, a major stream, runs directly by the mine site.

Abandoned underground coal mines (Herrin No. 6 Coal seam) underlie the city of Streator, the brick company, the abandoned shale pit, the active shale

pit, and adjacent areas (Treworgy and Bargh 1984). These mines, which form a large complex of interconnected workings, are flooded and discharge into the Vermillion River and one of its tributaries (U.S. Environ. Prot. Agency 1981). Only about 18 m (60 ft) below the ground surface, these mines are causing surface subsidence in the Streator area.

Site No. 13 was not considered further because it is close to the city of Streator; it is very close to the Vermillion River (mine site may be in the floodplain); it is overlying a shallow underground mine, which is probably partially caved and leaking into the river; and the shale mine is still active and may remain active for several additional years.

Site No. 14. Site No. 14 is located on the northwest edge of Chatsworth, which is 4.6 km (2.8 mi) west of I-57 in Livingston County. There are three abandoned pits about 5-7 m (16-23 ft) deep, which are partially filled with water to form lakes. The pit lakes are surrounded on at least two sides by residential and commercial areas. Yorkville Till was excavated from shallow pits at this site for use in the manufacture of clay drainage tiles. Because the pits are filled with water and are located so close to residential areas, the site was eliminated from further consideration.

Site No. 15. Site No. 15 is located on the south side of St. Anne in Kankakee County. One abandoned shallow pit, located on the south side of the high school, is filled with water to within about 2 m (7 ft) of the land surface. A little farther east, the Eastern Illinois Clay Company is operating a very shallow (<3 m) surface mine. The clay mined at this site is from the Yorkville Till (Lineback 1979), which is the same till member that was mined near Chatsworth and is found at the Alternative D site in Livingston County. Because this site is located on the edge of town and the site is still being actively mined, it was not considered further.

Site No. 16. The clay mine at Site No. 16 covers approximately 1 km² (0.4 mi²) in northeast Grundy County (Secs. 10 and 11, T33N, R8E). It is located about 6.4 km (4 mi) north of Coal City, 10 km (6 mi) east of Morris, 3.2 km (2 mi) south of the Dresden Nuclear Power Plant, 2 to 3 km (1 to 2 mi) from the Kankakee and Illinois rivers, and directly adjacent to Goose Lake Prairie State Park (see FES--Fig. 4.9). The mine is very large. Mining extended 3 to 5 m (10 to 15 ft) below the land surface to extract Pennsylvanian claystone and semiflint clay. The mine site is now abandoned, although it was reported to be active in 1980 by Kerr-McGee. Small spoil piles are interspersed with diked ponded areas, and the surrounding land is flat, consisting of marshy lowlands and wetlands. The elevation of this mine site is 0 to 2 m (0 to 7 ft) above the average stage level in the nearby Kankakee River; therefore, this area might be prone to flooding during high water stages.

Because this site is in a wetland area and directly adjacent to Goose Lake Prairie State Park, it was dismissed as a candidate site.

Site No. 17. Site No. 17 is located about 5 km (3 mi) east of Ottawa in La Salle County, just north of U.S. Route 6 (see FES--Fig. 4.10). Along the north side of Route 6 is a steep bluff that rises about 15 to 30 m (50 to 100 ft) above the river valley. The mine is located up on the bluff, with a highwall that extends southward to within about 30 m (100 ft) of the edge of the bluff. The large pit is about 10 to 13 m (30 to 40 ft) deep, so the base of the pit is probably below the elevation of Route 6 and may be as low as the valley of the Illinois River. Milliken Creek, which is located on the west and northwest sides of the mine, flows southwest into the Illinois River. Milliken Creek is separated from the pit area by a large bank of spoil material. Mining apparently proceeded from Milliken Creek southward until the pit approached the edge of the bluff; mining then proceeded eastward. The older east-west pit (parallel to Route 6) is filled with water. The newer north-south pit on the east edge of the mine also has some water in it. The dragline used for this operation is standing idle at the northeast corner of the site. Mining also occurred on the west side of Milliken Creek, but this area was not directly observed. Most of the spoil material appeared to be a hard, gray silty shale. Some thin layers of siltstone and sandstone were observed in the highwalls, generally near the top. Very little glacial material appeared to overlie the Pennsylvanian strata at the mine site.

This site was eliminated from further consideration because of the large quantities of coarse spoil materials, the very close proximity of the mine to Milliken Creek, the location of the mine in a bluff area where the rock is likely fractured, and the possibility that the mine site may be hydraulically linked to the alluvium in the Illinois River valley to the south.

Site No. 17A. Site No. 17A is located about 0.5 km (0.3 mi) east of Ottawa at the intersection of two major highways. The surrounding area is flat and above the floodplains of the nearby Illinois and Fox rivers. The mine is abandoned, and ponded water occurs between ridges of spoil material. Pennsylvanian shale or claystone was mined at this site, and the St. Peter Sandstone aquifer is directly beneath the clay. Because of its close proximity to Ottawa and a significant aquifer, this site was eliminated from further consideration.

Site No. 18. Site No. 18 is located at the northeast corner of the intersection of Illinois routes 178 and 71, which is 2 km (1 mi) south of Utica, 1.5 km (0.9 mi) south of the Illinois River, and 0.8 km (0.5 mi) south of Starved Rock State Park in La Salle County (see FES--Fig. 4.11). The mine is active intermittently; a small front-end loader was sitting at the site. The mined area totals about 8 ha (20 acres), and the depth of mining extends

about 8 to 10 m (25 to 30 ft) below the land surface. The surrounding land, which is generally flat farmland and woods, is about 50 m (150 ft) above the Illinois River floodplain. The upper 3 to 4 m (10 to 13 ft) of material in the pit appears to be Pleistocene sand and gravel. The sand and gravel unit has been extensively mined here and in surrounding areas. Below the sand and gravel lies about 2 m (7 ft) of shale, a thin coal (about 30 cm thick), and about 2 m (7 ft) of gray underclay. The shale, coal, and underclay are Pennsylvanian in age.

The south end of the pit appeared to be the area of most recent mining. The partially exposed coal seam was burning, with flames visible in the outcrop area. A few trenches had been dug down into the underclay (medium to light gray), and there was some water standing in the deepest areas. The water in this end of the pit was bright red (due to iron) and probably quite acidic. A few small spoil piles were sitting at various places on the pit floor.

According to Kerr-McGee (1980--p. 11.31), most residential wells in this area are completed in the St. Peter Sandstone (Ordovician) aquifer; one driller's log of a borehole located near the clay mine reports the top of the St. Peter Sandstone at a depth only 26 m (85 ft) below the land surface.

This site is unsuitable for waste disposal because it is located so close to a major state park, it overlies a major aquifer, the surrounding land has sand and gravel as its uppermost material, and the mine is still sporadically active.

Site No. 20. Site No. 20 is located about 1 km (0.5 mi) northwest of Lowell (Sec. 9, T32N, R2E). The gravel road approaching the site passes close to two or three houses. The mine is less than 100 m (300 ft) northeast of the Vermillion River and is possibly within its floodplain. Mining progressed away from the Vermillion River and eastward into the hillside. Flattened spoils occur between the pit and the river, and the highwall in the hillside is about 10 to 15 m (30 to 50 ft) high. Small pits extend along the contour of the hill toward the northwest. The water on the pit floor did not appear to be very deep. The terrain north and east of the highwall is hilly and mostly at a higher elevation. The spoil material observed from the top of the highwall appeared to be mostly shale and clay. The rock exposed in the highwall is predominantly shale.

This site is unsuitable for waste disposal because of the hilly topography, the close proximity to homes and the Vermillion River, and the small capacity of the mine pits for wastes.

A.7.5 Elimination of the Clay and Shale Mine Category

None of the clay and shale mine sites that were visited and evaluated appeared to be suitable for a waste-disposal site. The seven sites not visited are described in Kerr-McGee (1980). All of these could be easily dismissed for major reasons (e.g., too close to populations or streams). Hence, this category was eliminated for lack of a suitable candidate site.

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*In this reference list, (1) the term "personal communication" is used to indicate either a telephone conversation or a face-to-face conversation and (2) all letters and memos cited are on file. Copies are available upon request from S.Y. Tsai, Energy and Environmental Systems Division, Bldg. 362, Argonne National Laboratory, Argonne, Illinois 60439.

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APPENDIX B. DISPOSAL CELL DESIGNS

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B.1 INTRODUCTION

Disposal cell designs for the five disposal alternatives (see Chapter 3) are described in this appendix. Each conceptual design accommodates disposal of a total waste volume of about 282,000 m³ (369,000 yd³). The main factors considered in developing a design for containment of the Kerr-McGee wastes include (1) governmental regulations, (2) potential causes of containment failure, (3) characteristics of the disposal site, and (4) characteristics of the wastes.

Disposition of the radioactive Kerr-McGee wastes is governed by regulations that apply to mill tailings, U.S. Environmental Protection Agency (EPA) regulations in 40 CFR Part 192 and U.S. Nuclear Regulatory Commission (NRC) regulations in 10 CFR Part 40. A number of standards in 40 CFR Part 192 and 10 CFR Part 40 (Appendix A) bear directly on disposal cell design. The regulations formulated by EPA have the following general objectives: (1) prevent misuse of the wastes by humans, (2) prevent dispersal of the wastes by wind and water, (3) protect groundwater quality, (4) limit radon emissions, and (5) limit exposure to gamma radiation. Regulations significant for containment design are summarized in Table B.1.

Containment failure could be caused by one or more of the following: (1) penetration and damage of the cover by flooding; (2) erosion of the cover by wind or precipitation; (3) slope failure; (4) differential settlement of the wastes; (5) infiltration by precipitation; (6) intrusion by humans, plants, or animals; (7) seismic damage; (8) penetration by gully development in surrounding land; and (9) penetration by a change in the channel of a nearby stream (Nelson et al. 1983). These possible failures were considered in disposal cell design and/or site selection.

Several site characteristics are important in determining disposal cell design (Timm 1985): (1) topographic features, e.g., the slope of the surrounding land and natural drainage patterns; (2) geometry of ready-made cavities, if the wastes are to be placed in existing pits or mines; (3) properties of the geologic medium surrounding and underlying the wastes, especially its permeability; (4) capability of the site to support vegetation on the waste cover; (5) availability of materials for cover construction (e.g., sand, clay, riprap, and topsoil); and (6) elevation of the water table.

The physical characteristics and the specific radioactivities of various portions of the wastes would have some effect on the cross section of the disposal cell. Emplacement of wastes in the cell would be designed to avoid differential settlement.

Table B.1. Regulatory Guidance for Disposal Cell Design

Guidance	Source
• The disposal cell should be effective in meeting the performance objectives for 1,000 years and, in any case, for at least 200 years.	40 CFR Part 192.32(b)(1)(i) 10 CFR Part 40, App. A, Criterion 1
• Placement below grade is the prime option, in mines or specially excavated pits where the need for any specially constructed retention structure is eliminated. Where below-grade burial is not practicable, evaluation of a proposed above-grade disposal cell must show that it would provide "reasonably equivalent isolation [as compared to below-grade disposal] of the tailings from erosional forces." The consideration of alternatives must reflect serious consideration of below-grade disposal.	10 CFR Part 40, App. A, Criterion 3
• In general, slopes should not be steeper than about 5H:1V. A cover of rock^a or self-sustaining vegetation must be used, except for cases involving special conditions favoring erosion resistance.	10 CFR Part 40, App. A, Criterion 4(c), 4(d)
• Impoundment surfaces should be contoured to avoid concentrated surface runoff or sharp slope	10 CFR Part 40, App. A, Criterion 4(d)
• Areas toward which runoff is directed should be protected with rock cover.	10 CFR Part 40, App. A, Criterion 4(d)
• Impoundment should incorporate features to promote deposition of sediment, promoting an increase in cover thickness with time.	10 CFR Part 40, App. A, Criterion 4(f)
• For clay liners, reaction of clay with representative tailings leachate should be tested.	10 CFR Part 40, App. A, Criterion 5
• Radioactivity in the cover materials must not exceed that of the surrounding surface soils.	10 CFR Part 40, App. A, Criterion 6

^a The regulations suggest that rocks be cobble size; be zoned by size; and be dense, resistant to abrasion, and free of cracks and defects. Cobbles are defined as 5 to 25 cm (2 to 10 in.) in diameter (Merritt 1976--p. 7-3).

Components common to several designs suggested for other remedial action projects are correlated in Table B.2 with the function that they would be expected to perform in containing the Kerr-McGee wastes (U.S. Dept. Energy 1983; Bechtel Natl. 1984, 1985; Thiers et al. 1984; Keshian and Bone 1985). The purpose of many of the functions is to prevent the failure scenarios listed above.

The following general disposal cell concepts can accommodate the proposed alternatives for disposal of the Kerr-McGee wastes: (1) above-grade containment, (2) deep-trench burial, (3) underground containment (sufficiently deep so that the wastes would be emplaced by transport through shafts or slope entrances connecting the surface with the emplacement area), and (4) partial burial (sufficiently shallow so that the wastes would be emplaced into an uncovered excavation).

Table B.2. Components Commonly Used in Disposal Cells and Their Functions

Component	Function
Cover	
Topsoil layer	Support vegetation.
Sand layer(s)	Divert infiltrated water away from wastes to periphery of cell; act as transition layer to prevent topsoil from entering other layers.
Geomembrane(s)	Provide distinct separation of layers of different geologic media during construction.
Riprap layer	Resist intrusion by humans, animals, and roots.
Clay layer	Act as a radon barrier; divert infiltrated water.
Liner	Protect groundwater.
Base	Provide floor for wastes; provide protective foundation for liner.
Structural fill	Adjust level of wastes; fill void above or below waste layer.
Dike	Restrict lateral movement of wastes; resist intrusion of floodwaters.
Vegetation	Reduce erosion of cover; provide evapotranspiration of water from top surface of cover.
Drainage swale	Channel runoff around bottom periphery of embankment; prevent undercutting of containment cell.
Internal drain	Provide for dewatering and management of leachate.

B.2 ABOVE-GRADE DISPOSAL AT THE WEST CHICAGO SITE (PROPOSED ACTION)

The conceptual design for an above-grade disposal cell developed by Kerr-McGee Chemical Corporation is indicated in a plan view (Figure B.1) and two cross sections (Figures B.2 and B.3). This cell would be used for disposal of the Kerr-McGee wastes on the West Chicago site (Proposed Action) described in Sections 3.2 and 4.6.1.

The lowermost component of the conceptual above-grade disposal cell would be a 0.61-m (2-ft) thick liner of compacted clay having a coefficient of permeability ranging from 5×10^{-6} to 5×10^{-8} cm/s. Near-surface clays existing at the West Chicago site would be placed above the prepared subgrade (capillary barrier) and compacted.

A leachate system in the cell would provide the capability for detecting and removing any water collected in the cell during construction and for detecting leaks in the cover following closure. The leachate system would consist of a 0.3-m (1-ft) sand and gravel filter-drain with perforated drain pipes at the base of the disposal cell that would slope toward the perimeter of the cell. The drain pipes would be connected to perforated manifold pipes (the drain pipes have the same function as the sand and gravel filter-drain and are not considered vital to system performance). Risers connected to the manifold pipe would be embedded in the berm to provide a well for monitoring, sampling, and removing accumulated leachates. It is planned to remove the upper portions of the risers and to plug the lower portions of the leachate-monitoring system riser a few years after cell closure. These actions should eliminate any risk that the integrity of the cap would be compromised by the monitoring well.

A geotextile fabric would be installed above the sand and gravel filter-drain to minimize disturbance of the filter-drain during emplacement of the first lift of wastes. Long life is not required for this component. Soil particles would form a filter of their own as they accumulated on the face of the fabric, thus providing a natural filter between the wastes and the filter-drain. This natural filter would remain even though the geotextile fabric might deteriorate. No long-term credit has been taken in the cell design for the presence of this or any other geotextile layer.

The waste layer would have a maximum depth of approximately 9.7 m (32 ft). If additional volume was necessary, the north berm would be extended onto the Intermediate Site (see Figure 3.1)

The lowermost component of the cell cover would be a 0.61-m (2-ft) thick clay layer, placed immediately above the wastes. The thickness of this layer was chosen to satisfy the NRC guidelines concerning radon release rates

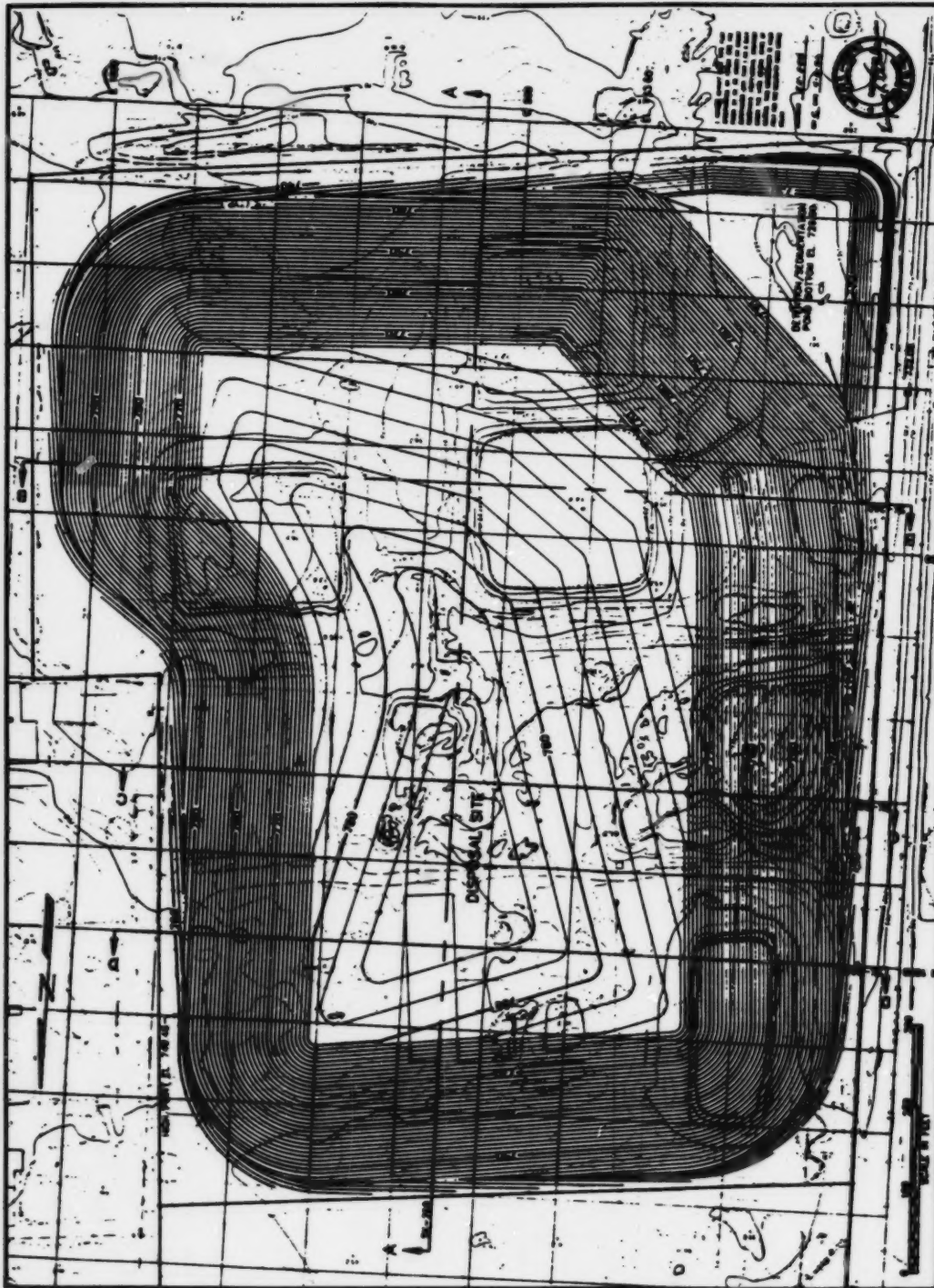
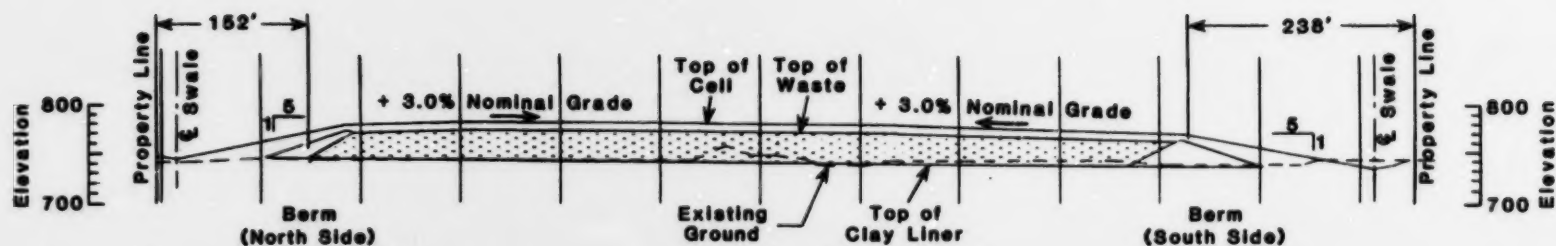


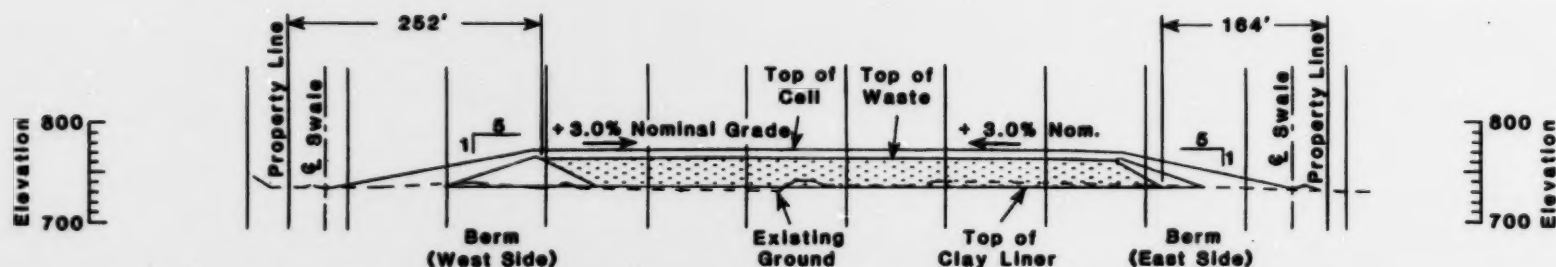
Figure B.1. Conceptual Plan View of the Above-Grade Disposal Cell.
Source: Kerr-McGee (1986--Vol. IV.)

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Section A-A



Section B-B

Figure B.2. Cross Sections of the Conceptual Plan View in Figure B.1.
Source: Redrawn from Kerr-McGee (1986--Vol. IX).

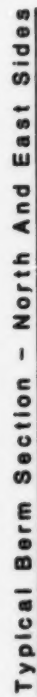


Figure B.3. Detailed Cross Section of the Above-Grade Disposal Cell.
Source: Redrawn from Kerr-McGee (1986---Vol. IV).

(Rogers et al. 1984). The material would be obtained from local off-site borrow sources. The soils would be chosen and the compaction operations controlled to achieve a coefficient of permeability of $\leq 10^{-8}$ cm/s in this layer. Bentonite would be added to the soil, if necessary, to achieve this permeability.

A temporary cell cover would initially be placed over the wastes to allow time for waste consolidation before placement of the permanent clay layer. (This approach should minimize the potential for damage to the permanent clay layer through settlement.) The temporary cover would then be partially removed, the surface regraded as necessary, and the permanent cover installed. The top of the permanent clay layer would be rolled smooth after compaction. A permeable geotextile fabric would be installed above the permanent clay layer to keep the materials of the clay cap separate from the materials of the capillary break above it during construction.

A 0.3-m (1-ft) thick sand and gravel capillary break would be installed over the clay layer. This layer would provide a pathway for water infiltrating the upper surface of the cell to drain away from the cell. Lateral movement of water would be facilitated by the difference in permeability between the capillary break material and the clay layer. The coefficient of permeability for the sand and gravel used in the capillary break would be $\geq 10^{-2}$ cm/s, or one million times the permeability of the clay. This uncontaminated drainage would be conducted to a similar sand and gravel capillary break on the outer perimeter of the clay berm and then to the shallow sand and gravel layer (E stratum) underlying the site.

A permeable geotextile fabric would be installed between the sand and gravel capillary break and the low-permeability soil layer above it. This fabric would minimize disturbance of the sand and gravel capillary break during placement of subsequent layers of material. The 0.3-m (1-ft) thick layer of low-permeability soil would be extended 12 m (40 ft) down the side of the berm. This layer would prevent the larger stones of the intrusion barrier from being pushed into the sand and gravel capillary break; it would also function as a barrier to the downward migration of soil moisture, thus allowing the topsoil to retain sufficient moisture for vegetative growth. The soils would be chosen and the compaction operations controlled to achieve a coefficient of permeability of $\leq 10^{-7}$ cm/s in the low-permeability soil layer.

A permeable geotextile fabric would be installed between the low-permeability soil layer and the intrusion barrier above to separate the two layers during construction. The 0.61-m (2-ft) thick intrusion barrier, to be composed of graded clays to cobbles, would constitute a barrier to intrusion into the cell by small animals and a deterrent to easy intrusion by humans. It would also provide for erosion control.

The uppermost component of the disposal cell would be a 0.61-m (2-ft) thick layer of topsoil, which would be suitable for establishing a vegetative cover that would resist erosion and have a coefficient of permeability of 10^{-6} cm/s.

Two techniques of berm construction would be used for the disposal cell. The berms on the south and west sides of the disposal cell would be built to full height with clay (see Figure B.3). Constructing these full-height clay berms would facilitate control of surface runoff during cell construction. The berms on the north and east sides of the disposal cell would be constructed with clay material for their outer portions and selected waste material for their inner portions. The initial 1.2-m (4-ft) height of the berms along the east and north sides would be constructed of clay material. A layer of waste would then be placed to within approximately 0.3 m (1 ft) of the top of the initial berm. The next layer of clay material would then be placed, followed by another layer of waste. Alternating layers would be placed until the berm attained its final waste elevation.

Clay material for the berms would be obtained from nearby off-site borrow sources and would be the same type of material used for the clay cover. The choice of soils and the methods of placement and compaction would be controlled to achieve a coefficient of permeability of $\leq 10^{-8}$ cm/s.

A 0.91-m (3-ft) thick sand and gravel capillary break having a coefficient of permeability of $\geq 10^{-3}$ cm/s would be placed in horizontal lifts above the outer slope of the clay berm around the perimeters of the cell. The functions of the sand and gravel capillary break are to:

- Prevent the clay berm from drying through capillary action,
- Provide lateral movement of water away from the berm and into the shallow sand and gravel layer underlying the site,
- Provide a pathway to drain the sand and gravel capillary break in the cell cover to the shallow sand and gravel layer underlying the site, and
- Provide a suitable surface for vehicular traffic during construction activities.

On the berm, a permeable geotextile fabric would be installed above the sand and gravel capillary break. This fabric would provide a distinct interface between the capillary break and the finer-grained soils of the selected fill layer above it.

The selected fill layer in berm construction would provide a transition from the 3:1 slope for the inner component of the berm to a 5:1 slope for the final cover of the berm. Excess E stratum material, obtained from grading for the base of the cell, could be used for this layer, provided that it met strength requirements. The remainder of the material would be obtained from nearby off-site borrow sources.

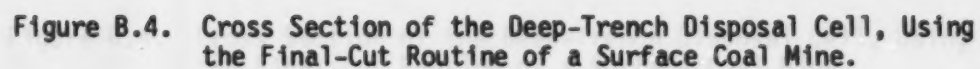
On the berm, a 0.61-m (2-ft) thick intrusion barrier, which is a continuation of the intrusion barrier on the top of the disposal cell, would be placed above the selected fill layer. It would be composed of graded clays to cobbles and would have a coefficient of permeability of about 10^{-6} cm/s. This intrusion barrier would also protect the underlying layers, if the topsoil were removed by erosion.

The cover on the surface of the 5:1 slopes of the berm would be a 0.61-m (2-ft) thick layer of topsoil. The soil would be suitable for establishing vegetation that would reduce erosion. Clean topsoil stripped from the disposal site would be used to the maximum extent possible. Topsoil obtained from off-site borrow sources would be used as necessary.

B.3 DEEP-TRENCH DISPOSAL AT A SURFACE COAL MINE (ALTERNATIVES A AND B)

Disposal of the Kerr-McGee wastes in a conceptual deep trench is shown in Figure B.4. The excavation for the deep trench would be the final-cut pit of an active or reclaimed surface coal mine (Alternatives A and B, respectively). The Alternative A site is described in Sections 3.3 and 4.6.2, and Appendix A, Section A.3; the Alternative B site is described in Sections 3.4 and 4.6.3, and in Appendix A, Section A.4. For this concept, the floor of the cell was assumed to be at a depth of about 21 m (70 ft), with the waste layer entirely below the water table (e.g., more than 6.1 m below the land surface).

Final-cut mine pits typically have one wall of minespoil materials with a slope of about 45°. Four measurements of hydraulic conductivity of minespoils in northeastern Fulton County and western Peoria County ranged from 3.6×10^{-8} to 1.0×10^{-5} m/s (Midland Coal Co. 1984). These values could potentially allow seepage into and out of a disposal cell. Therefore, a low-permeability liner for the spoil wall would be constructed by piling up lifts of silty clay till, each about 1 m (3.3 ft) high and 6.1 m (20 ft) wide. Each lift would be compacted before the next one was added. For the active surface mine, the materials for this clay liner would be till, which would be stockpiled at the edge of the highwall (Section 3.3, Figure 3.3). The highwall of the final cut typically has a slope of about 85°, undisturbed soil and rock strata, and relatively low hydraulic conductivity (e.g., $<10^{-8}$ m/s). For the inactive mine, however, the clay liner for the spoil wall would have to be obtained



either by excavating and sieving some of the spoil materials (to eliminate rocks and gravel) or by excavating till from surface layers beyond the mined area (see Section 3.4.1, Figure 3.5).

The length of final-cut ravines varies, but is typically about 700 m (2,300 ft). The wastes would be covered with 6.1 m (20 ft) of silty clay, and each 1-m (3.3-ft) layer would be compacted after it was put down. This clay layer is much thicker than necessary to meet the EPA radon-release limit. Because the wastes would be remote from the surface, the cross-sectional structure of the cover does not include a drainage layer or intrusion barrier. To support vegetation, the thick clay layer would be covered with a layer of topsoil with center-to-edge slopes of 3%. Although a greater waste thickness would be possible, resulting in the use of less land area, the thickness of 15 m (50 ft) suggested by the concept described in Figure B.4 has the advantage that the waste layer would be located below the zone of water table fluctuations.

B.4 UNDERGROUND CONTAINMENT SYSTEM (ALTERNATIVE C)

The underground containment concept (described as Alternative C in Sections 3.5 and 4.6.4, and in Appendix A, Section A.5) involves emplacing the Kerr-McGee wastes in one or more worked-out panels of an underground coal mine. The general form and structure of the disposal cell would be determined by the volume of void space remaining after the coal was extracted from the panel(s) of a room-and-pillar mine. The wastes would be emplaced into the corridors between pillars; in the Ziegler Murdock Mine, these corridors are typically 5.5 m (18 ft) wide and about 2 m (6 ft) high. Figure B.5 is a plan view of a typical panel, and Figure B.6 is a cross-sectional view of wastes in a panel.

Several considerations would affect the application of this concept: (1) selection of both the mine and the panel(s) for favorable hydrological conditions; (2) equipment and procedures needed to support the waste-emplacement operations; and (3) closing procedures. In selecting an underground coal mine for waste disposal (see Appendix A, Section A.5.4), an important criterion is minimal seepage into the mine. Within a given mine, selecting the panel(s) to be used for waste disposal would also be based on criteria that include minimal seepage. The ventilation system and the materials-transport system used to move the wastes into the mine would be very important during waste-emplacement operations. Dust would be controlled by spraying the wastes with water immediately before moving them into the mine. After waste-emplacement operations were complete, mine sealing could include filling the shafts and slope entrances with clean earthen materials, and placing concrete plugs at both the bottom and top of the mine entrances.

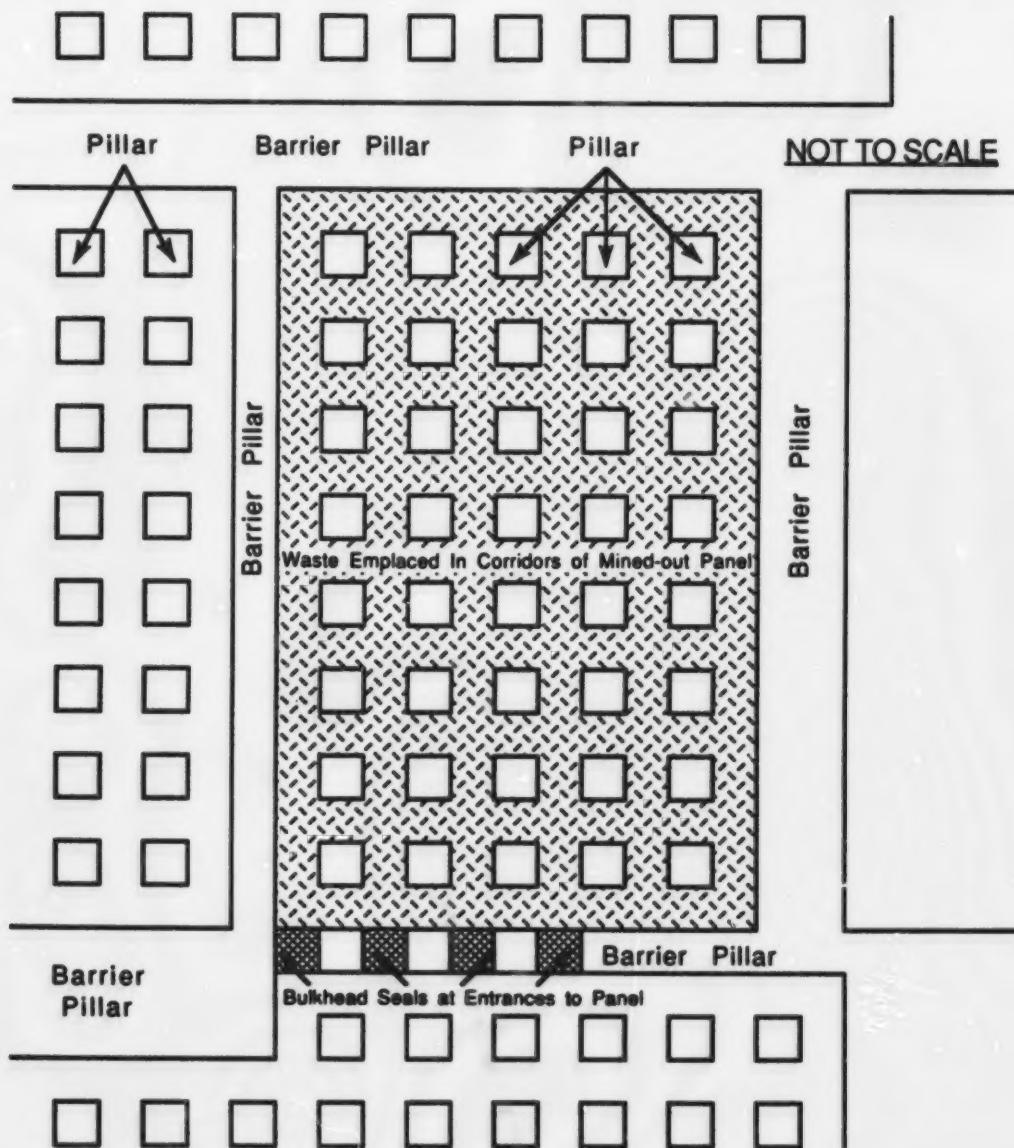


Figure B.5. Conceptual Plan View of the Underground Containment System for a Coal Mine.

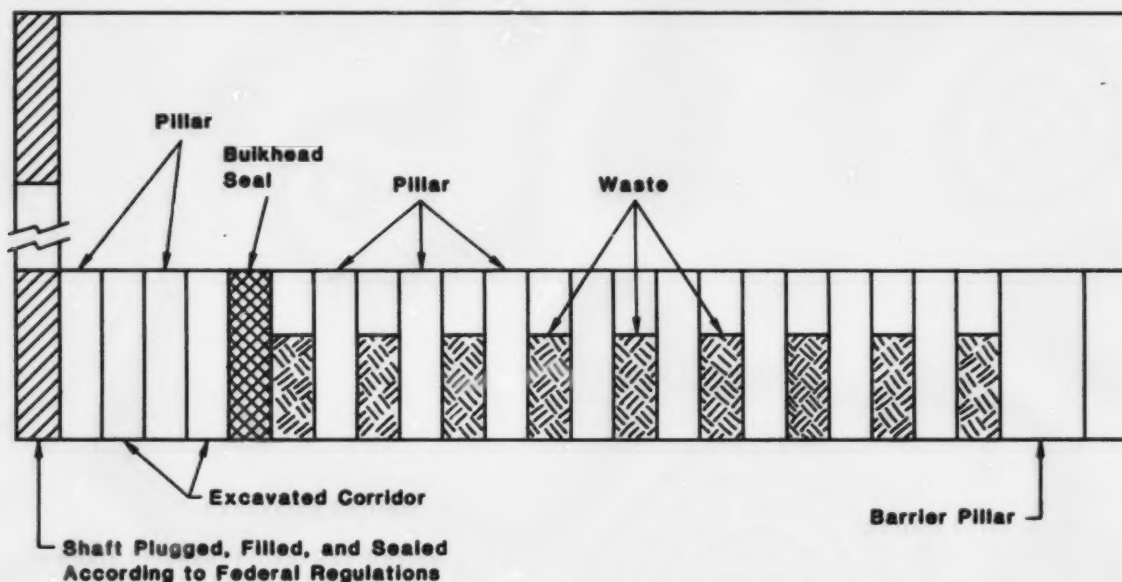
Not to Scale

Figure B.6. Cross Section of the Conceptual Underground Containment System for a Coal Mine.

The techniques used to emplace the Kerr-McGee wastes would be restricted by their physical form: moist soils, building rubble, and fragments of processing equipment. These forms are unsuitable for pneumatic emplacement, slurring, or funneling through boreholes. Furthermore, reversing the coal conveyer system to transport the wastes down into the disposal area might prove impractical. Using shaft hoists would be the most practical means of transporting containerized wastes into the mine. These wastes would then be transported to the disposal panel by coal-haulage vehicles and piled into the corridors of a panel to a depth convenient for materials-handling equipment. These types of vehicles are in normal use in mines. After the wastes were emplaced, the entrances to the panel would be sealed according to normal practice, that is, by constructing walls of solid brick or concrete to cover each panel entrance. More resistant barriers could be constructed if necessary. Typical panels have three to five entrances.

An average panel in the Murdock Mine has an area of about 30 ha (74 acres). The room height is about 2 m (7 ft), and the extraction ratio (void-space-area/total-area) is about 40%. Therefore, the total void space in a panel of average size is about $2.4 \times 10^5 \text{ m}^3$ ($3.1 \times 10^5 \text{ yd}^3$). Wastes cannot be packaged to fill the void spaces up to the mine ceiling. Therefore, some

empty space would remain after disposal operations. Two panels of average size would probably be required to hold the Kerr-McGee wastes.

This underground containment concept should achieve the general objectives of the EPA regulations (see Section B.1). Because of the distance from the wastes to the land surface, radon emanating from the wastes would decay before reaching the surface. Therefore, it would not be necessary to cover the wastes with a special radon barrier. Also, this concept should provide an effective barrier to humans, plants, and animals because the wastes would be so remote from the surface environment, i.e., the disposal area would not be easily accessible from the surface, and the peripheral coal pillars of the panel and the seals at the entrances to the panel would provide additional barriers.

B.5 PARTIAL BURIAL ON A FARMLAND SITE (ALTERNATIVE D)

A conceptual design for partial burial of the Kerr-McGee wastes on farmland (Alternative D) is presented in Figure B.7. The Alternative D site is described in Sections 3.6 and 4.6.5, and in Appendix A, Section A.6.

In this conceptual disposal cell, the wastes would lie partially below grade but above the water table. The configuration of the waste embankment would be determined by the following requirements: (1) a 3% slope for the cover over the wastes and a 20% slope from the edge of the wastes to the grade surface; (2) a square layout, so that the solid geometry of the waste embankment is that of a square pyramid sitting on a cuboid, with the above-grade edges and corners contoured; and (3) a floor depth of 1.2 m (4 ft) below surrounding grade.

Construction of this disposal cell would require excavating a square 1.2 m (4 ft) deep; 0.61 m (2 ft) of topsoil and the same thickness of the underlying clay would be stripped off. These materials would be kept in separate stockpiles for later use in constructing the cover. The cell would have a 0.3-m (1-ft) thick sand drain, slightly inclined to a sump and incorporating a drainage tile system like that described for the above-grade cell (see Section B.2). Because of the volume occupied by the sand drain on the floor of the cell, wastes lying below grade would be 0.91 m (3 ft) thick.

The length of the sides of the disposal cell and the enclosed area were calculated based on the requirements discussed above and the volume of the wastes. Thus, the wastes would lie within a square with sides 335 m (1,100 ft) long, and the cover and its flanks would lie within a square with sides 366 m (1,200 ft) long. The area occupied by the cover and flanks would be 13.4 ha (33 acres). In this configuration, 35% of the waste volume would lie below grade.

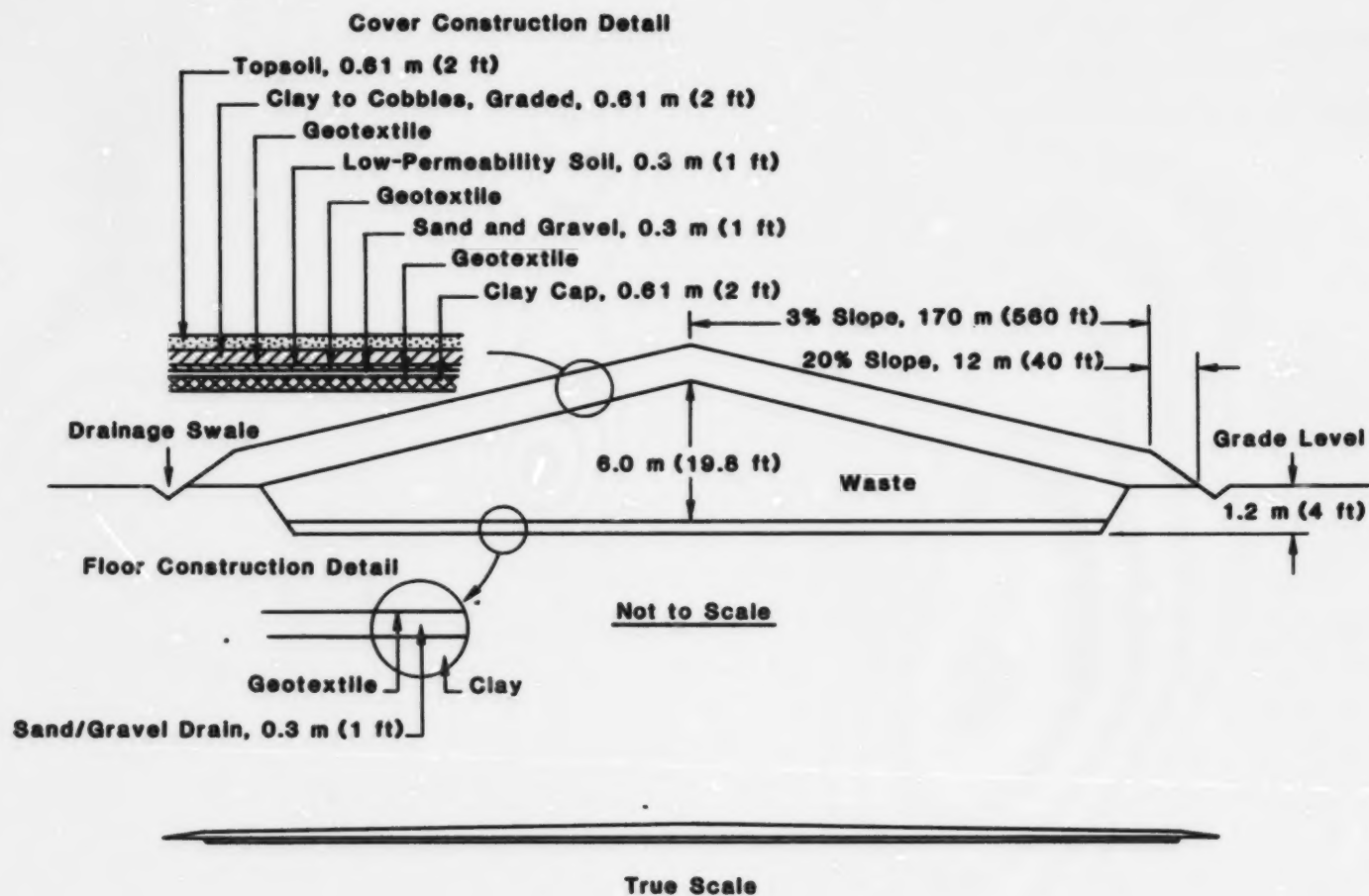


Figure B.7. Cross Section of the Partial-Burial Disposal Cell for the Farmland Site.

The cover for the partial-burial disposal cell would have the same cross-sectional construction as the above-grade disposal cell described in Section B.2. Construction of berms to confine the wastes laterally would be unnecessary for this disposal cell design.

B.6 SUMMARY OF LAND USE FOR PROPOSED ACTION AND ALTERNATIVES

Estimates of the land areas that would be used by the Proposed Action and its alternatives are presented in Table B.3. Areas for two types of land-use commitment are considered: (1) a long-term commitment of the land needed to support containment of wastes and (2) a short-term commitment of the land needed to support various cleanup and disposal activities such as interim storage of wastes, stockpiling of earthen materials associated with disposal cell construction, storage and maintenance of equipment, and management of wastewater and runoff.

Table B.3. Estimated Land Area Commitments for Disposal of the Kerr-McGee Wastes

Disposal Alternative	Short-Term Commitment ^a (acres)	Long-Term Commitment ^b (acres)		
		Waste ^c	Border ^d	Total
Proposed Action, Above-grade burial at the West Chicago site	16 ^e	13 ^f	14 ^f	27
Alternatives A and B, Deep-trench burial at a surface coal mine	10 ^g	6.4	14 ^h	20
Alternative C, Burial in an underground coal mine	10 ^g	150	40 ^h	190
Alternative D, Shallow burial at a farmland site	10 ^g	29	18 ^h	47

^a For construction and interim storage.

^b For waste disposal.

^c Area within perimeter of waste layer.

^d Border beyond edge of waste layer.

^e Sum of Factory and Intermediate sites at the West Chicago site.

^f Estimated from drawings by Kerr-McGee (1986--Vol. IV).

^g Estimated by Argonne National Laboratory technical staff.

^h Calculated for 46-m (150-ft) width.

Long-term land use for the Proposed Action was estimated from Kerr-McGee drawings (Kerr-McGee 1986). For each of the alternatives to the Proposed Action, the land area committed to long-term disposal was estimated from the area within the perimeter of the waste layer plus a border of 46 m (150 ft). This border width was chosen to be the same as the minimum distance from the edge of the waste layer to the property line suggested for the Proposed Action at West Chicago.

Short-term land use for the Proposed Action was taken to be the sum of the Factory and Intermediate sites at the West Chicago site, or 6.5 ha (16 acres). For each of the alternatives to the Proposed Action, the land needed for short-term use was estimated to be 4 ha (10 acres). This area was judged to be sufficient for any temporary stockpiling of wastes or construction materials that might be required.

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APPENDIX C. GROUNDWATER CHARACTERISTICS
OF THE WEST CHICAGO SITE

Table C.1. Concentrations of Chemical and Radiological Parameters at Different Times in the B Wells on the West Chicago Site, Well B-1

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	<0.002	<0.002	<0.002
Al	mg/L	0.20	<0.005	0.15	0.21	0.29
As	mg/L	0.046	0.10	0.003	0.021	0.028
B	mg/L	00.24	0.36	0.009	0.34	0.33
Ba	mg/L	0.013	0.19	0.10	0.11	0.17
Ca	mg/L	210.	320.	250.	220.	280.
Cd	mg/L	<0.001	<0.002	0.003	<0.002	<0.002
Co	mg/L	0.011	0.014	0.012	<0.006	0.014
Cr	mg/L	<0.001	0.010	<0.001	0.002	<0.001
Cu	mg/L	0.023	0.11	0.069	<0.001	0.08
Fe	mg/L	0.047	0.13	0.11	3.6	0.13
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	1.4	38.	3.0	2.4	3.
Mg	mg/L	85.	110.	95.	80.	97.
Mn	mg/L	0.64	0.94	0.96	0.15	0.9
Mo	mg/L	0.016	0.18	0.007	0.009	0.002
Na	mg/L	250.	450.	650.	540.	670.
N1	mg/L	0.067	0.12	0.011	0.073	0.11
Pb	mg/L	0.003	0.05	0.003	0.02	<0.004
Se	mg/L	0.001	0.14	<0.001	0.066	0.21
V	mg/L	0.011	<0.003	0.015	<0.003	<0.003
Zn	mg/L	0.57	1.2	1.3	0.006	1.2
F	mg/L	17.	17.	18.	17.	18.
Cl	mg/L	210.	330.	315.	250.	290.
HCO ₃	mg/L	367.	334.	496.	470.	473.
CO ₃	mg/L	-	30.	<6.	<3.	<10.
NH ₃ (N)	mg/L	2.	<0.1	5.	4.3	6.4
NO ₂ (N)	mg/L	<0.1	0.23	<0.1	7.5	<0.1
NO ₃ (N)	mg/L	6.	3.	4.	4.	3.2
SO ₄	mg/L	770.	1580.	1630.	1350.	1610.
TDS	mg/L	1762.	3030.	3290.	2660.	3330.
TSS	mg/L	3.	6.	<2.	<2.	<2.
pH	units	6.8	7.1	7.	7.2	6.9
Sp.Cond.	µmhos	2398.	3860.	4180.	3190.	4150.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.12	0.15	0.10	0.19	0.06
Ra-228	pCi/L	1.04	<2.8	<1.2	<2.4	<2.2
Th-230	pCi/L	0.037	0.196	0.042	0.046	0.022
Th-232	pCi/L	0.004	0.018	0.014	0.015	0.003
U-238	mg/L	0.001	0.016	0.02	0.006	0.008

Table C.1. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	0.035	0.085	0.059	<0.020
Al	mg/L	<0.05	0.25	0.45	0.47	0.16
As	mg/L	0.003	<0.1	0.20	0.11	<0.11
B	mg/L	0.27	0.28	0.36	0.59	0.32
Ba	mg/L	<0.001	<0.02	<0.02	<0.013	<0.013
Ca	mg/L	220.	220.	210.	210.	200.
Cd	mg/L	<0.002	<0.01	0.016	0.009	<0.007
Co	mg/L	0.011	<0.04	0.056	0.040	<0.011
Cr	mg/L	<0.001	<0.03	0.056	0.052	<0.026
Cu	mg/L	0.077	0.092	0.12	0.14	0.081
Fe	mg/L	0.11	0.093	0.11	0.059	0.10
Hg	mg/L	0.00013	<0.0001	0.00023	0.00092	0.00034
K	mg/L	3.	2.7	2.5	4.	2.8
Mg	mg/L	80.	70.	71.	78.	71.
Mn	mg/L	0.68	0.61	0.63	0.62	0.56
Mo	mg/L	0.017	0.032	0.056	0.033	0.027
Na	mg/L	570.	440.	400.	420.	430.
Ni	mg/L	0.095	0.13	0.16	0.15	0.069
Pb	mg/L	<0.001	0.11	0.29	0.18	<0.068
Se	mg/L	0.002	0.099	0.22	0.10	<0.10
V	mg/L	<0.003	<0.04	0.081	0.050	0.031
Zn	mg/L	0.91	0.76	0.82	3.4	0.77
F	mg/L	17.	13.1	17.	16.	17.
Cl	mg/L	260.	150.	170.	190.	190.
HCO ₃	mg/L	480.	750.	460.	420.	420.
TOC	mg/L	-	-	-	-	22.
NH ₃ (N)	mg/L	7.	<0.1	4.8	5.4	<0.1
NO ₂ (N)	mg/L	7.	0.1	0.14	<0.04	<0.01
NO ₃ (N)	mg/L	<1.	11.	2.	2.	<1.
SO ₄	mg/L	1310.	760.	950.	1020.	1160.
TDS	mg/L	2710.	2160.	2130.	2240.	2360.
TSS	mg/L	<2.	3.	<2.	<1.	1.
pH	units	7.3	7.7	6.8	6.7	6.8
Sp. Cond.	µmhos	3890.	2810.	2730.	3540.	3050.
Ra-224	pCi/L	0.03	0.08	0.0002	0.03	-
Ra-226	pCi/L	0.06	0.13	0.5	0.09	0.008
Ra-228	pCi/L	<1.3	<2.5	-	-	0.09(s)
Th-230	pCi/L	0.047	0.004	0.009	-	0.021
Th-232	pCi/L	0.008	0.004	0.006	-	0.006
U-238	mg/L	0.004	0.0009	0.003	0.002	0.014

Table C.1. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.048	<0.002
Al	mg/L	0.18	0.15	0.23	0.70
As	mg/L	0.14	<0.11	0.12	<0.06
B	mg/L	0.37	0.31	0.38	0.52
Ba	mg/L	<0.013	<0.013	0.007	0.11
Ca	mg/L	260.	210.	290.	200.
Cd	mg/L	0.010	<0.007	0.024	<0.002
Co	mg/L	0.026	0.017	0.054	<0.006
Cr	mg/L	<0.026	<0.026	0.043	<0.001
Cu	mg/L	0.062	0.066	0.083	<0.001
Fe	mg/L	0.046	0.054	0.097	0.070
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.0005
K	mg/L	2.1	1.9	2.37	9.8
Mg	mg/L	72.	70.	68.	60.
Mn	mg/L	0.79	0.54	0.63	0.48
Mo	mg/L	0.023	0.018	0.046	0.010
Na	mg/L	380.	350.	300.	340.
Ni	mg/L	0.096	0.080	0.11	0.002
Pb	mg/L	<0.068	<0.068	0.21	<0.008
Se	mg/L	<0.10	<0.10	0.11	<0.08
V	mg/L	0.021	0.014	0.059	<0.003
Zn	mg/L	1.1	1.3	0.88	0.49
F	mg/L	20.	21.	21.	20.
Cl	mg/L	190.	160.	180.	150.
HCO ₃	mg/L	450.	390.	390.	430.
TOC	mg/L	8.5	20.	24.	9.4
NH ₃ (N)	mg/L	7.2	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	<0.05	0.06	-	-
NO ₃ (N)	mg/L	<1.	<1.	7.	<1.
SO ₄	mg/L	1030.	890.	800.	680.
TDS	mg/L	2210.	1990.	1960.	1800.
TSS	mg/L	3.	<2.	<2.	9.
pH	units	6.9	6.8	6.8	6.9
Sp. Cond.	µmhos	3330.	2920.	2940.	2710.
Ra-224	pCi/L	0.14	-	0.07	-
Ra-226	pCi/L	0.08	0.04	-	-
Ra-228	pCi/L	0.05(s)	0.14	0.07	0.12
Th-230	pCi/L	0.022	0.014	0.022	0.086
Th-232	pCi/L	0.013	0.005	0.006	0.010
U-238	mg/L	0.003	0.019	0.012	0.014

Source: Munson and Lambert (1981-1985).

Table C.2. Concentrations of Chemical and Radiological Parameters at Different Times in the B Wells on the West Chicago Site, Well B-2

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	<0.002	<0.002	<0.002
Al	mg/L	0.025	<0.05	<0.050	0.21	0.11
As	mg/L	0.025	<0.009	0.004	0.018	0.006
B	mg/L	0.14	0.16	<0.009	0.21	0.10
Ba	mg/L	0.018	0.21	0.13	0.11	0.097
Ca	mg/L	110.	120.	100.	110.	97.
Cd	mg/L	<0.001	<0.002	<0.002	<0.002	<0.002
Co	mg/L	<0.001	<0.006	<0.006	<0.006	<0.006
Cr	mg/L	<0.001	0.021	0.003	0.002	<0.001
Cu	mg/L	<0.001	0.014	<0.001	<0.001	<0.001
Fe	mg/L	3.0	3.8	2.2	3.6	3.5
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	6.3	31.	5.5	5.4	5.2
Mg	mg/L	70.	63.	63.	58.	61.
Mn	mg/L	0.17	0.12	0.15	0.15	0.14
Mo	mg/L	0.012	0.018	0.003	0.009	0.003
Na	mg/L	200.	210.	250.	170.	200.
Ni	mg/L	0.071	0.088	0.082	0.073	0.065
Pb	mg/L	0.001	<0.001	<0.001	0.017	<0.004
Se	mg/L	0.002	0.028	<0.001	0.011	0.019
V	mg/L	0.004	0.023	0.011	<0.003	<0.003
Zn	mg/L	0.004	<0.003	<0.003	0.006	<0.003
F	mg/L	2.5	7.	1.4	2.	1.8
Cl	mg/L	94.	130.	110.	88.	100.
HCO ₃	mg/L	436.	326.	454.	400.	438.
CO ₃	mg/L	-	30.	<6.	<3.	<10.
NH ₃ (N)	mg/L	4.	<0.1	2.	<0.1	1.7
NO ₂ (N)	mg/L	<0.1	0.34	0.1	<0.1	<0.1
NO ₃ (N)	mg/L	<1.	1.	2.	2.	<1.
SO ₄	mg/L	540.	590.	540.	490.	460.
TDS	mg/L	1264.	1350.	1350.	1120.	1190.
TSS	mg/L	16.	97.	6.	56.	19.
pH	units	7.1	7.4	7.3	7.4	7.3
Sp. Cond.	µmhos	1831.	2500.	2000.	1490.	1700.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.26	0.39	0.17	0.33	0.21
Ra-228	pCi/L	<1.9	<4.5	<1.6	<1.5	<1.6
Th-230	pCi/L	0.015	0.032	0.048	0.024	0.031
Th-232	pCi/L	0.002	0.003	0.007	0.006	0.010
U-238	mg/L	0.005	0.005	0.006	0.001	0.003

Table C.2. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	0.035	0.079	0.029	<0.020
Al	mg/L	<0.05	<0.2	0.33	0.072	0.14
As	mg/L	0.002	<0.1	0.18	<0.1	<0.11
B	mg/L	0.18	0.38	0.12	0.26	0.13
Ba	mg/L	<0.001	<0.02	<0.02	0.013	0.017
Ca	mg/L	100.	110.	100.	98.	90.
Cd	mg/L	<0.002	0.011	0.015	<0.007	<0.007
Co	mg/L	<0.006	<0.04	<0.04	0.015	<0.011
Cr	mg/L	<0.001	<0.03	0.067	<0.03	<0.026
Cu	mg/L	<0.001	<0.03	0.056	0.033	0.027
Fe	mg/L	1.5	3.5	3.0	1.7	0.21
Hg	mg/L	<0.00008	<0.0001	<0.0001	<0.00030	0.00028
K	mg/L	5.	5.1	4.9	5.4	4.0
Mg	mg/L	53.	54.	53.	50.	50.
Mn	mg/L	0.15	0.16	0.15	0.12	0.13
Mo	mg/L	0.011	0.029	0.047	<0.02	0.024
Na	mg/L	180.	140.	130.	120.	140.
Ni	mg/L	0.062	0.099	0.15	0.086	0.042
Pb	mg/L	<0.001	0.12	0.26	0.10	<0.068
Se	mg/L	<0.001	0.10	0.20	<0.1	<0.10
V	mg/L	<0.003	<0.04	0.073	0.020	0.04
Zn	mg/L	0.015	0.070	0.045	0.036	0.023
F	mg/L	2.	1.3	3.	5.8	<1.
Cl	mg/L	96.	65.	64.	87.	66.
HCO ₃	mg/L	450.	355.	460.	410.	410.
TOC	mg/L	-	-	-	-	12.
NH ₃ (N)	mg/L	<1.	<0.1	2.6	2.9	<0.1
NO ₂ (N)	mg/L	0.1	0.1	0.14	1.2	0.28
NO ₃ (N)	mg/L	<1.	6.	2.	<1.	<1.
SO ₄	mg/L	430.	320.	280.	310.	310.
TDS	mg/L	1030.	910.	910.	840.	910.
TSS	mg/L	7.	18.	15.	<1.	19.
pH	units	7.7	7.5	7.2	7.1	7.1
Sp. Cond.	µmhos	1600.	1300.	1340.	1530.	1370.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.16	0.34	0.15	0.27	0.12
Ra-228	pCi/L	<1.4	<2.5	-	-	0.19(s)
Th-230	pCi/L	0.039	0.016	0.026	-	0.024
Th-232	pCi/L	0.007	0.004	0.006	-	0.009
U-238	mg/L	0.002	0.002	0.002	0.04	0.004

Table C.2. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	<0.020	<0.002
Al	mg/L	<0.0008	<0.008	<0.11	0.49
As	mg/L	<0.11	<0.11	<0.11	<0.06
B	mg/L	0.065	0.093	0.11	0.25
Ba	mg/L	<0.013	<0.013	0.011	0.17
Ca	mg/L	86.	92.	94.	91.
Cd	mg/L	<0.007	<0.007	<0.015	<0.002
Co	mg/L	<0.011	<0.011	<0.011	<0.006
Cr	mg/L	<0.026	<0.026	<0.026	<0.001
Cu	mg/L	<0.017	0.017	<0.015	<0.001
Fe	mg/L	1.3	0.32	<0.033	0.47
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.005
K	mg/L	3.0	4.2	4.0	9.4
Mg	mg/L	35.	49.	49.	48.
Mn	mg/L	0.14	0.12	0.11	0.091
Mo	mg/L	<0.018	<0.018	<0.018	0.006
Na	mg/L	130.	110.	115.	110.
Ni	mg/L	0.087	0.043	<0.069	0.027
Pb	mg/L	<0.068	<0.068	<0.050	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	<0.005	0.005	<0.025	<0.003
Zn	mg/L	0.41	0.18	0.024	0.042
F	mg/L	<1.	<1.	2.	3.
Cl	mg/L	58.	60.	80.	36.
HCO ₃	mg/L	420.	400.	400.	400.
TOC	mg/L	7.5	19.	15.	11.
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	<0.05	1.7	-	-
NO ₃ (N)	mg/L	<1.	<1.	<1.	<1.
SO ₄	mg/L	180.	210.	250.	180.
TDS	mg/L	750.	740.	750.	660.
TSS	mg/L	25.	630.	7.	35.
pH	units	7.2	7.5	7.3	7.3
Sp. Cond.	µmhos	1280.	1330.	1210.	1180.
Ra-224	pCi/L	1.85	-	-	0.03
Ra-226	pCi/L	0.36	0.14	0.	0.14
Ra-228	pCi/L	0.04(s)	0.18	0.15	0.30
Th-230	pCi/L	0.029	0.024	0.028	0.183
Th-232	pCi/L	0.005	0.012	0.003	0.015
U-238	mg/L	0.002	0.007	0.005	0.002

Source: Munson and Lambert (1981-1985).

Table C.3. Concentrations of Chemical and Radiological Parameters at Different Times in the B Wells on the West Chicago Site, Well B-3

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	<0.002	0.009	<0.002
Al	mg/L	0.26	0.72	0.36	0.88	0.3
As	mg/L	0.037	0.026	0.004	0.25	0.008
B	mg/L	1.4	1.29	0.73	0.83	0.83
Ba	mg/L	0.016	0.20	0.13	0.11	0.091
Ca	mg/L	240.	280.	240.	230.	220.
Cd	mg/L	0.001	0.010	0.004	0.006	<0.002
Co	mg/L	0.018	0.032	0.018	0.009	0.011
Cr	mg/L	<0.001	0.038	<0.001	0.025	<0.001
Cu	mg/L	0.098	0.52	0.22	0.13	0.1
Fe	mg/L	0.050	0.056	0.029	0.076	0.044
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	2.7	47.	2.6	2.5	3.0
Mg	mg/L	150.	130.	130.	120.	110.
Mn	mg/L	1.5	1.3	1.4	1.3	1.5
Mo	mg/L	0.013	0.034	0.003	0.024	<0.002
Na	mg/L	180.	250.	270.	190.	210.
Ni	mg/L	0.17	0.27	0.27	0.18	0.18
Pb	mg/L	0.001	0.001	0.002	0.031	<0.004
Se	mg/L	0.007	0.052	0.001	0.032	0.036
V	mg/L	0.036	0.085	0.028	0.016	<0.003
Zn	mg/L	0.88	1.2	1.3	0.90	0.81
F	mg/L	18.	16.	6.	15.	17.
Cl	mg/L	160.	370.	300.	140.	250.
HCO ₃	mg/L	369.	280.	402.	370.	374.
CO ₃	mg/L	-	30.	<6.	<3.	<10.
NH ₃ (N)	mg/L	4.	<1.	3.	0.8	2.5
NO ₂ (N)	mg/L	<0.1	3.20	<0.1	4.4	<0.1
NO ₃ (N)	mg/L	2.	<1.	3.	2.	2.9
SO ₄	mg/L	990.	970.	850.	790.	800.
TDS	mg/L	2044.	2300.	2120.	1850.	1950.
TSS	mg/L	2.	144.	7.	2.	<2.
pH	units	6.6	6.8	6.8	0.	6.7
Sp. Cond.	μmhos	2616.	3110.	2840.	2140.	2580.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.16	0.33	0.10	0.07	1.14
Ra-228	pCi/L	<3.	<4.4	<1.1	<2.1	<2.
Th-230	pCi/L	0.011	0.149	0.072	0.029	0.021
Th-232	pCi/L	0.004	0.007	0.010	0.003	0.006
U-238	mg/L	0.019	0.017	0.02	0.01	0.009

Table C.3. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	0.036	0.098	0.066	<0.020
Al	mg/L	0.14	0.36	0.63	0.45	0.31
As	mg/L	0.003	<0.1	0.22	0.13	<0.11
B	mg/L	0.98	1.2	0.96	1.5	1.1
Ba	mg/L	<0.001	<0.02	<0.02	<0.013	0.019
Ca	mg/L	240.	240.	250.	330.	280.
Cd	mg/L	<0.002	0.012	0.020	0.012	<0.007
Co	mg/L	0.025	0.048	0.071	0.053	0.034
Cr	mg/L	0.005	0.033	0.088	0.045	<0.026
Cu	mg/L	0.21	0.15	0.13	0.15	0.19
Fe	mg/L	0.053	0.083	0.094	0.071	0.085
Hg	mg/L	<0.00008	<0.0001	0.00038	<0.00030	0.0034
K	mg/L	3.0	2.8	3.0	5.5	3.5
Mg	mg/L	121.	120.	120.	170.	190.
Mn	mg/L	1.5	1.5	1.8	2.6	3.2
Mo	mg/L	0.016	0.032	0.061	0.027	0.022
Na	mg/L	260.	190.	140.	200.	300.
Ni	mg/L	0.23	0.21	0.24	0.24	0.23
Pb	mg/L	<0.001	0.16	0.32	0.18	<0.068
Se	mg/L	0.003	<0.1	0.31	0.15	<0.10
V	mg/L	<0.003	0.049	0.10	0.067	0.041
Zn	mg/L	1.1	0.96	0.93	1.1	1.5
F	mg/L	16.	14.	14.	15.	15.
Cl	mg/L	300.	200.	110.	270.	200.
HCO ₃	mg/L	380.	325.	400.	350.	360.
TOC	mg/L	-	-	-	-	18.
NH ₃ (N)	mg/L	2.	<0.1	3.7	3.6	<0.1
NO ₂ (N)	mg/L	25.	0.2	0.08	<0.04	0.28
NO ₃ (N)	mg/L	<1.	7.	1.	<1.	<1.
SO ₄	mg/L	830.	780.	770.	1410.	1450.
TDS	mg/L	2030.	1790.	1760.	2520.	2830.
TSS	mg/L	<2.	3.	<2.	<1.	<2.
pH	units	7.2	6.7	6.6	6.5	6.4
Sp. Cond.	µmhos	2890.	2480.	2310.	3780.	3570.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.03	0.06	0.09	0.09	0.13
Ra-228	pCi/L	<1.3	<1.8	-	-	0.16(s)
Th-230	pCi/L	0.034	0.014	0.046	-	0.014
Th-232	pCi/L	0.008	0.004	0.007	-	-
U-238	mg/L	0.01	0.003	0.02	0.016	-

Table C.3. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.046	<0.002
Al	mg/L	0.19	0.35	0.53	1.7
As	mg/L	<0.11	<0.11	<0.11	<0.06
B	mg/L	0.33	0.98	0.90	1.2
Ba	mg/L	<0.013	<0.013	0.009	0.17
Ca	mg/L	150.	210.	300.	250.
Cd	mg/L	<0.007	<0.007	0.029	<0.002
Co	mg/L	0.037	0.022	0.088	<0.006
Cr	mg/L	<0.026	<0.026	0.040	<0.001
Cu	mg/L	0.054	0.068	0.14	<0.001
Fe	mg/L	0.051	0.024	0.086	0.047
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.005
K	mg/L	1.6	3.6	3.9	25.
Mg	mg/L	60.	110.	140.	160.
Mn	mg/L	1.6	2.2	3.0	2.8
Mo	mg/L	<0.018	<0.018	0.038	0.010
Na	mg/L	73.	170.	180.	190.
Ni	mg/L	0.12	0.16	0.27	0.17
Pb	mg/L	<0.068	<0.068	0.20	<0.08
Se	mg/L	<0.10	<0.10	0.13	<0.08
V	mg/L	0.009	0.026	0.080	<0.003
Zn	mg/L	0.81	0.92	1.3	0.88
F	mg/L	12.	18.	22.	20.
Cl	mg/L	78.	170.	230.	95.
HCO ₃	mg/L	200.	340.	350.	410.
TOC	mg/L	20.	11.	13.	11.
NH ₃ (N)	mg/L	1.0	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	1.7	4.0	-	-
NO ₃ (N)	mg/L	<1.	1.	2.	<1.
SO ₄	mg/L	520.	710.	910.	970.
TDS	mg/L	1050.	1680.	1890.	2020.
TSS	mg/L	3.	140.	115.	9.
pH	units	6.6	6.6	6.5	6.6
Sp. Cond.	µmhos	1660.	2460.	2730.	2660.
Ra-224	pCi/L	0.04	0.13	-	0.02
Ra-226	pCi/L	0.031	0.	0.	0.03
Ra-228	pCi/L	0.12(s)	0.08	0.06	0.20
Th-230	pCi/L	0.029	0.039	0.033	0.031
Th-232	pCi/L	0.010	0.004	0.016	0.011
U-238	mg/L	0.006	0.011	0.010	0.010

Source: Munson and Lambert (1981-1985).

Table C.4. Concentrations of Chemical and Radiological Parameters at Different Times in the B Wells on the West Chicago Site, Well B-4

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	0.010	<0.002	<0.002
Al	mg/L	0.21	0.48	0.22	0.28	0.46
As	mg/L	0.024	<0.010	0.006	0.013	0.008
B	mg/L	0.18	0.22	<0.009	0.19	0.20
Ba	mg/L	0.002	0.22	0.15	0.18	0.12
Ca	mg/L	120.	150.	210.	130.	170.
Cd	mg/L	<0.001	<0.002	<0.002	<0.002	<0.002
Co	mg/L	<0.001	<0.006	<0.006	<0.006	<0.006
Cr	mg/L	0.001	0.012	0.002	<0.001	0.001
Cu	mg/L	0.015	0.035	0.003	<0.001	<0.001
Fe	mg/L	0.019	0.021	0.021	0.014	0.023
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	0.88	19.	0.8	0.7	1.
Mg	mg/L	50.	55.	52.	54.	63.
Mn	mg/L	0.11	0.13	0.14	0.13	0.15
Mo	mg/L	0.019	0.022	0.007	0.012	<0.002
Na	mg/L	72.	63.	63.	60.	99.
Ni	mg/L	0.004	0.024	0.013	0.014	0.014
Pb	mg/L	0.002	<0.001	<0.001	0.015	<0.004
Se	mg/L	0.008	0.035	0.002	0.017	0.019
V	mg/L	0.046	0.044	0.047	0.094	0.027
Zn	mg/L	0.20	0.23	0.21	0.22	0.29
F	mg/L	22.	21.	21.	19.	18.
Cl	mg/L	95.	150.	100.	180.	300.
HCO ₃	mg/L	295.	293.	353.	300.	310.
CO ₃	mg/L	-	<10.	<6.	<3.	<10.
NH ₃ (N)	mg/L	4.	<0.1	3.	2.4	3.8
NO ₂ (N)	mg/L	<0.1	0.05	<0.1	0.1	<0.1
NO ₃ (N)	mg/L	3.	1.	4.	4.	3.
SO ₄	mg/L	180.	210.	230.	140.	220.
TDS	mg/L	765.	796.	806.	800.	1130.
TSS	mg/L	2.4	13.	18.	6.	3.
pH	units	6.8	7.1	6.9	7.3	6.9
Sp. Cond.	µmhos	1199.	1360.	1260.	1060.	1600.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.17	0.35	0.39	0.05	0.02
Ra-228	pCi/L	<2.5	<3.4	<1.	<1.8	<2.6
Th-230	pCi/L	<0.019	0.046	0.037	0.019	0.027
Th-232	pCi/L	0.003	0.007	0.007	0.003	0.006
U-238	mg/L	0.079	0.12	0.14	0.10	0.10

Table C.4. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	0.088	<0.020	<0.020
Al	mg/L	0.24	0.28	0.54	0.24	0.20
As	mg/L	0.002	<0.1	0.20	<0.11	<0.11
B	mg/L	0.15	0.22	0.18	0.28	0.17
Ba	mg/L	0.15	<0.02	<0.02	<0.013	<0.013
Ca	mg/L	140.	120.	150.	140.	100.
Cd	mg/L	<0.002	<0.01	0.015	<0.007	<0.007
Co	mg/L	<0.006	<0.04	0.044	<0.011	<0.011
Cr	mg/L	<0.001	<0.03	0.066	<0.026	<0.026
Cu	mg/L	<0.001	0.032	0.073	0.040	0.024
Fe	mg/L	0.009	<0.05	<0.05	<0.024	<0.024
Hg	mg/L	<0.00009	0.00017	<0.0001	0.00035	0.00053
K	mg/L	0.8	1.1	0.92	1.9	0.92
Mg	mg/L	58.	49.	57.	61.	41
Mn	mg/L	0.15	0.13	0.15	0.14	0.095
Mo	mg/L	0.014	0.026	0.052	0.019	0.020
Na	mg/L	120.	91.	68.	110.	90.
Ni	mg/L	0.010	<0.08	0.08	<0.038	<0.038
Pb	mg/L	<0.001	<0.1	0.28	<0.068	<0.068
Se	mg/L	0.004	<0.1	0.20	<0.10	<0.10
V	mg/L	0.004	0.050	0.11	0.051	0.054
Zn	mg/L	0.25	0.25	0.30	0.31	0.17
F	mg/L	17.	17.	17.	16.	19.
Cl	mg/L	320.	180.	140.	230.	90.
HCO ₃	mg/L	370.	290.	370.	330.	340.
TOC	mg/L	-	-	-	-	6.
NH ₃ (N)	mg/L	3.	2.	2.3	2.4	<0.1
NO ₂ (N)	mg/L	<0.1	<0.1	1.2	<0.04	<0.01
NO ₃ (N)	mg/L	2.	6.	4.	3.	4.2
SO ₄	mg/L	130.	110.	140.	140.	160.
TDS	mg/L	1000.	760.	840.	840.	720.
TSS	mg/L	<2.	5.	<2.	<1.	<2.
pH	units	7.6	7.2	6.9	6.8	1210.
Sp. Cond.	µmhos	1750.	1300.	1470.	1770.	1210.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.01	0.10	0.04	0.15	0.16
Ra-228	pCi/L	<1.4	<1.7	-	-	0.15(s)
Th-230	pCi/L	0.025	0.065	0.018	-	0.046
Th-232	pCi/L	0.008	0.009	0.004	-	0.007
U-238	mg/L	0.14	0.10	0.15	0.11	0.11

Table C.4. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.02	<0.020	<0.020	<0.002
Al	mg/L	0.25	0.15	0.18	0.62
As	mg/L	<0.11	<0.11	<0.11	<0.060
B	mg/L	0.19	0.13	0.15	0.29
Ba	mg/L	<0.013	<0.013	<0.002	0.16
Ca	mg/L	140.	130.	130.	100.
Cd	mg/L	<0.007	<0.007	<0.015	<0.002
Co	mg/L	0.012	<0.011	0.015	<0.006
Cr	mg/L	<0.026	<0.026	<0.026	<0.001
Cu	mg/L	<0.017	<0.017	0.019	<0.001
Fe	mg/L	<0.024	<0.024	<0.033	<0.006
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.0005
K	mg/L	0.62	1.2	1.1	<0.03
Mg	mg/L	40	4.8	52	42.
Mn	mg/L	0.14	0.13	0.12	0.087
Mo	mg/L	0.029	0.018	0.026	<0.002
Na	mg/L	75.	210.	170.	130.
Ni	mg/L	<0.038	<0.038	<0.069	<0.003
Pb	mg/L	<0.068	<0.068	0.075	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	0.038	0.035	0.050	<0.003
Zn	mg/L	0.38	0.46	0.21	0.17
F	mg/L	21.	18.	18.	18.
Cl	mg/L	88.	480.	350.	110.
HCO ₃	mg/L	330.	280.	370.	360.
TOC	mg/L	2.5	21.	16.	7.9
NH ₃ (N)	mg/L	2.8	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	<0.05	0.10	-	-
NO ₃ (N)	mg/L	2.0	4.	5.	3.
SO ₄	mg/L	240.	71.	100.	98.
TDS	mg/L	830.	1050.	990.	720.
TSS	mg/L	2.	11.	<2.	1.
pH	units	6.8	6.8	6.9	7.0
Sp. Cond.	µmhos	1540.	2110.	1780.	1300.
Ra-224	pCi/L	0.09	0.98	0.01	0.04
Ra-226	pCi/L	0.05	0.	0.	0.
Ra-228	pCi/L	0.21(s)	0.65	0.13	0.15
Th-230	pCi/L	0.007	0.357	0.076	0.067
Th-232	pCi/L	0.014	0.003	0.006	0.026
U-238	mg/L	0.14	0.066	0.15	0.16

Source: Munson and Lambert (1981-1985).

Table C.5. Concentrations of Chemical and Radiological Parameters at Different Times in the B Wells on the West Chicago Site, Well B-5

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	0.025	<0.002	<0.002
Al	mg/L	0.19	0.31	0.19	0.12	0.32
As	mg/L	0.056	0.027	0.002	0.02	0.010
B	mg/L	0.43	0.48	<0.009	0.36	0.32
Ba	mg/L	0.014	0.19	0.13	0.13	0.11
Ca	mg/L	260.	250.	230.	340.	230.
Cd	mg/L	<0.001	<0.002	0.005	<0.002	<0.002
Co	mg/L	0.009	0.009	<0.006	<0.006	<0.0006
Cr	mg/L	<0.001	0.018	0.009	0.004	0.01
Cu	mg/L	0.076	0.20	0.074	0.044	0.07
Fe	mg/L	0.024	0.43	0.023	0.011	0.028
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	3.	27.	2.4	2.3	2.
Mg	mg/L	92.	75.	80.	110.	80.
Mn	mg/L	0.83	0.49	0.56	0.73	0.6
Mo	mg/L	0.013	0.026	0.017	<0.002	0.007
Na	mg/L	320.	210.	300.	380.	240.
Ni	mg/L	0.11	0.11	0.10	0.13	0.085
Pb	mg/L	<0.001	<0.001	0.004	0.03	<0.004
Se	mg/L	0.010	0.026	<0.001	0.11	0.045
V	mg/L	0.012	0.020	0.032	0.081	0.013
Zn	mg/L	0.52	0.49	0.40	0.45	0.44
F	mg/L	18.	16.	17.	13.	16.
Cl	mg/L	91.	93.	89.	67.	90.
HCO ₃	mg/L	329.	246.	372.	350.	346.
CO ₃	mg/L	-	20.	<6.	<3.	<10.
NH ₃ (N)	mg/L	7.	<0.1	3.	3.8	3.4
NO ₂ (N)	mg/L	<0.1	1.47	<0.1	1.8	<0.1
NO ₃ (N)	mg/L	4.	2.	7.	5.	3.1
SO ₄	mg/L	1310.	960.	1030.	1690.	850.
TDS	mg/L	2375.	1840.	2030.	3040.	1850.
TSS	mg/L	<2.	50.	30.	24.	12.
pH	units	6.9	7.	7.	7.2	6.8
Sp. Cond.	µmhos	2943.	2400.	2580.	3140.	2380.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.27	0.09	0.13	0.14	0.06
Ra-228	pCi/L	2.31	<3.3	<2.	<2.5	<1.8
Th-230	pCi/L	0.031	0.036	0.042	0.010	0.021
Th-232	pCi/L	0.003	0.006	0.024	0.003	0.003
U-238	mg/L	0.022	0.020	0.02	0.01	0.01

Table C.5. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	0.060	0.011	0.077	<0.020
Al	mg/L	0.12	0.29	0.56	0.40	0.17
As	mg/L	0.001	<0.1	0.24	0.11	<0.11
B	mg/L	0.43	0.11	0.55	0.56	0.43
Ba	mg/L	<0.001	<0.02	<0.02	<0.013	0.016
Ca	mg/L	210.	290.	300.	260.	240.
Cd	mg/L	<0.002	0.014	0.018	0.012	<0.007
Co	mg/L	<0.006	0.041	0.068	0.044	<0.011
Cr	mg/L	0.002	0.040	0.090	0.040	<0.026
Cu	mg/L	0.072	0.11	0.14	0.13	0.076
Fe	mg/L	0.011	0.051	0.080	0.061	0.025
Hg	mg/L	<0.0009	<0.0001	<0.0001	<0.00030	0.00025
K	mg/L	1.8	2.5	2.5	4.1	2.1
Mg	mg/L	70.	88.	87.	92.	82.
Mn	mg/L	0.49	0.68	0.70	0.61	0.47
Mo	mg/L	0.022	0.048	0.071	0.040	0.033
Na	mg/L	180.	230.	260.	260.	170.
Ni	mg/L	0.077	0.15	0.18	0.14	0.042
Pb	mg/L	<0.001	0.18	0.38	0.21	<0.068
Se	mg/L	0.007	0.013	0.28	0.20	<0.10
V	mg/L	<0.003	0.042	0.098	0.060	0.029
Zn	mg/L	0.43	0.49	0.54	0.50	0.35
F	mg/L	15.	15.	17.	17.	17.
Cl	mg/L	90.	88.	77.	92.	85.
HCO ₃	mg/L	350.	315.	370.	310.	330.
TOC	mg/L	-	-	-	-	11.
NH ₃ (N)	mg/L	<1.	<0.1	3.3	3.	<0.1
NO ₂ (N)	mg/L	0.5	<0.1	0.04	0.04	<0.01
NO ₃ (N)	mg/L	<1.	9.	3.	<1.	<1.
SO ₄	mg/L	660.	960.	1060.	1260.	880.
TDS	mg/L	1520.	1840.	2180.	2105.	1650.
TSS	mg/L	2.	6.	3.	4.	<2.
pH	units	7.3	6.8	6.9	6.7	6.7
Sp. Cond.	μmhos	2080.	2590.	2520.	3070.	2100.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.05	0.09	0.12	0.12	0.23
Ra-228	pCi/L	<1.5	<2.	-	-	0.27(s)
Th-230	pCi/L	0.043	0.021	0.027	-	0.027
Th-232	pCi/L	0.005	0.003	0.007	-	0.006
U-238	mg/L	0.02	0.009	0.02	0.016	0.018

Table C.5. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.024	<0.002
Al	mg/L	0.10	0.12	0.15	0.83
As	mg/L	<0.11	<0.11	0.13	<0.06
B	mg/L	0.54	0.44	0.44	0.85
Ba	mg/L	<0.013	0.013	0.010	0.18
Ca	mg/L	240.	330.	270.	260.
Cd	mg/L	0.008	<0.007	0.016	<0.002
Co	mg/L	0.025	0.022	0.029	<0.006
Cr	mg/L	<0.026	0.035	0.049	<0.001
Cu	mg/L	0.044	0.041	0.052	<0.001
Fe	mg/L	0.033	0.024	0.037	0.022
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.0005
K	mg/L	1.5	2.4	1.8	12.
Mg	mg/L	58.	110.	78.	78.
Mn	mg/L	0.59	0.66	0.54	0.48
Mo	mg/L	0.061	0.035	0.054	0.033
Na	mg/L	200.	290.	120.	190.
Ni	mg/L	0.064	0.076	0.085	0.045
Pb	mg/L	<0.068	<0.068	0.10	<0.08
Se	mg/L	<0.10	<0.10	0.12	<0.08
V	mg/L	0.008	0.024	0.034	<0.003
Zn	mg/L	0.46	0.47	0.30	0.25
F	mg/L	18.	26.	19.	17.
Cl	mg/L	72.	110.	100.	45.
HCO ₃	mg/L	320.	310.	290.	330.
TOC	mg/L	16.	14.	15.	11.
NH ₃ (N)	mg/L	2.3	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	0.50	1.0	-	-
NO ₃ (N)	mg/L	2.0	3.	2.	2.
SO ₄	mg/L	950.	1290.	670.	770.
TDS	mg/L	1710.	2420.	1410.	1680.
TSS	mg/L	<2.	1040.	79.	100.
pH	units	6.9	6.8	6.8	6.9
Sp. Cond.	μmhos	2690.	3280.	1890.	2180.
Ra-224	pCi/L	0.12	0.70	-	-
Ra-226	pCi/L	0.14	0.86	0.	0.02
Ra-228	pCi/L	0.05(s)	0.78	0.31	0.20
Th-230	pCi/L	0.039	0.006	0.064	0.120
Th-232	pCi/L	0.034	0.006	0.015	0.003
U-238	mg/L	0.011	0.019	0.015	0.014

Source: Munson and Lambert (1981-1985).

Table C.6. Concentrations of Chemical and Radiological Parameters at Different Times in the B Wells on the West Chicago Site, Well B-6

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	0.009	<0.002	<0.002
Al	mg/L	0.018	<0.05	<0.050	0.31	0.24
As	mg/L	0.052	0.015	0.022	0.044	0.020
B	mg/L	0.32	0.32	0.065	0.31	0.22
Ba	mg/L	0.014	0.26	0.16	0.21	0.12
Ca	mg/L	110.	110.	97.	110.	110.
Cd	mg/L	<0.001	<0.002	<0.002	0.002	<0.002
Co	mg/L	0.001	<0.006	0.007	0.014	<0.006
Cr	mg/L	<0.001	0.014	0.002	0.023	0.008
Cu	mg/L	0.001	0.002	<0.001	0.027	<0.001
Fe	mg/L	1.6	1.4	0.75	1.8	1.9
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	8.3	34.	6.8	6.	5.6
Mg	mg/L	82.	69.	70.	70.	72.
Mn	mg/L	0.35	0.33	0.41	0.43	0.37
Mo	mg/L	0.020	0.022	0.005	0.012	0.005
Na	mg/L	100.	76.	85.	90.	79.
Ni	mg/L	0.069	0.058	0.046	0.055	0.042
Pb	mg/L	0.002	<0.001	0.003	0.024	<0.004
Se	mg/L	0.003	0.019	0.004	0.013	0.015
V	mg/L	0.004	0.011	0.010	0.054	0.01
Zn	mg/L	0.084	0.040	0.049	0.049	0.074
F	mg/L	5.7	5.2	5.	5.	4.9
Cl	mg/L	120.	120.	120.	130.	130.
HCO ₃	mg/L	431.	244.	436.	420.	431.
CO ₃	mg/L	-	22.	<6.	<3.	<10.
NH ₃ (N)	mg/L	16.	<0.1	12.	7.6	12.4
NO ₂ (N)	mg/L	<0.1	0.37	<0.1	0.6	<0.1
NO ₃ (N)	mg/L	<1.	7.	<1.	2.	<1.
SO ₄	mg/L	290.	260.	260.	250.	240.
TDS	mg/L	955.	903.	871	890.	910.
TSS	mg/L	80.	410.	21.	375.	320.
pH	units	7.	7.1	7.2	7.4	7.3
Sp. Cond.	µmhos	1548.	1320.	1480.	1300.	1440.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.46	0.43	0.23	0.83	0.05
Ra-228	pCi/L	1.3	<2.7	<1.	<1.2	<1.9
Th-230	pCi/L	0.025	0.70	0.036	0.031	0.055
Th-232	pCi/L	0.003	0.009	-	0.003	0.006
U-238	mg/L	0.094	0.004	0.012	0.004	0.003

Table C.6. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	0.035	0.061	0.033	<0.020
Al	mg/L	<0.05	<0.2	0.22	0.10	0.12
As	mg/L	0.023	<0.1	0.14	<0.11	<0.11
B	mg/L	0.31	0.40	0.30	0.40	0.28
Ba	mg/L	<0.001	0.027	0.026	0.015	0.016
Ca	mg/L	110.	120.	120.	120.	110.
Cd	mg/L	<0.002	<0.01	0.011	<0.007	<0.007
Co	mg/L	<0.006	<0.04	<0.04	0.022	<0.011
Cr	mg/L	0.002	<0.03	0.044	<0.026	0.029
Cu	mg/L	<0.001	<0.03	0.042	0.034	0.019
Fe	mg/L	3.3	3.5	2.9	1.4	0.30
Hg	mg/L	<0.00009	<0.0001	<0.0001	<0.00030	0.00031
K	mg/L	5.	5.1	4.9	5.9	4.7
Mg	mg/L	71.	75.	73.	78.	78.
Mn	mg/L	0.38	0.46	0.46	0.43	0.39
Mo	mg/L	0.020	0.029	0.036	<0.018	0.029
Na	mg/L	80.	79.	76.	81.	83.
Ni	mg/L	0.045	0.084	0.10	0.082	0.051
Pb	mg/L	<0.001	0.10	0.21	0.085	<0.068
Se	mg/L	0.005	<0.1	0.14	<0.10	0.11
V	mg/L	<0.003	<0.04	0.049	0.025	0.024
Zn	mg/L	0.093	0.17	0.11	0.087	0.099
F	mg/L	4.	3.7	6.	3.2	<1.
Cl	mg/L	130.	120.	120.	120.	150.
HCO ₃	mg/L	430.	400.	470.	420.	410.
TOC	mg/L	-	-	-	-	23.
NH ₃ (N)	mg/L	13.	<0.1	12.	13.	<0.1
NO ₂ (N)	mg/L	25.	<0.1	0.14	1.	<0.01
NO ₃ (N)	mg/L	<1.	14.	2.	<1.	<1.
SO ₄	mg/L	220.	220.	250.	240.	230.
TDS	mg/L	840.	880.	950.	870.	920.
TSS	mg/L	25.	23.	14.	17.	21.
pH	units	7.5	7.2	7.1	7.	7.0
Sp. Cond.	µmhos	1430.	1510.	1420.	1770.	1470.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.42	0.37	0.53	0.36	0.07
Ra-228	pCi/L	<1.	<2.	-	-	0.20(s)
Th-230	pCi/L	0.021	0.045	0.019	-	0.057
Th-232	pCi/L	0.004	0.007	0.006	-	0.003
U-238	mg/L	0.006	0.003	0.002	0.002	0.010

Table C.6. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.025	<0.002
Al	mg/L	<0.008	0.013	<0.11	0.78
As	mg/L	<0.11	<0.11	<0.11	<0.06
B	mg/L	0.28	0.30	0.31	0.68
Ba	mg/L	<0.013	0.016	0.015	0.19
Ca	mg/L	120.	110.	130.	130.
Cd	mg/L	<0.007	<0.007	0.017	<0.002
Co	mg/L	<0.011	<0.011	0.026	0.018
Cr	mg/L	<0.026	<0.026	0.027	<0.001
Cu	mg/L	<0.017	<0.017	0.016	<0.001
Fe	mg/L	0.84	0.79	0.88	3.0
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.005
K	mg/L	3.9	4.2	3.8	14.
Mg	mg/L	70.	74.	77.	77.
Mn	mg/L	0.50	0.42	0.45	0.44
Mo	mg/L	0.019	0.024	0.035	0.045
Na	mg/L	82.	83.	69.	97.
Ni	mg/L	0.087	0.059	<0.069	0.050
Pb	mg/L	<0.068	<0.068	0.12	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	<0.005	<0.005	0.030	<0.003
Zn	mg/L	0.24	0.23	0.050	0.106
F	mg/L	3.0	7.2	4.	5.
Cl	mg/L	120.	180.	170.	140.
HCO ₃	mg/L	410.	340.	340.	420.
TOC	mg/L	7.6	22.	18.	8.1
NH ₃ (N)	mg/L	11.	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	<0.05	0.04	-	-
NO ₃ (N)	mg/L	<1.	<1.	<1.	<1.
SO ₄	mg/L	250.	220.	220.	180.
TDS	mg/L	920.	910.	890.	870.
TSS	mg/L	16.	9.	8.	10.
pH	units	7.1	7.0	6.9	7.2
Sp. Cond.	μmhos	1540.	1640.	1420.	1420.
Ra-224	pCi/L	0.09	0.05	0.03	-
Ra-226	pCi/L	0.28	0.07	0.14	0.17
Ra-228	pCi/L	0.01(s)	0.47	0.05	0.23
Th-230	pCi/L	0.019	0.027	0.034	0.039
Th-232	pCi/L	0.0041	0.006	0.007	0.011
U-238	mg/L	0.001	0.002	0.003	0.004

Source: Munson and Lambert (1981-1985).

Table C.7. Concentrations of Chemical and Radiological Parameters at Different Times in the B Wells on the West Chicago Site, Well B-7

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	0.043	<0.002	<0.002
Al	mg/L	0.042	0.42	0.19	0.26	0.19
As	mg/L	0.016	0.009	0.005	0.021	0.004
B	mg/L	0.25	0.26	0.071	0.31	0.26
Ba	mg/L	0.019	0.27	0.16	0.21	0.11
Ca	mg/L	140.	150.	120.	130.	140.
Cd	mg/L	<0.001	0.005	0.005	<0.002	<0.002
Co	mg/L	0.007	<0.006	0.010	<0.006	<0.006
Cr	mg/L	<0.001	0.024	0.015	0.014	<0.001
Cu	mg/L	0.020	0.091	0.027	0.024	<0.001
Fe	mg/L	0.013	0.034	0.020	0.012	0.023
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	1.	20.	1.	0.8	1.
Mg	mg/L	56.	52.	47.	49.	55.
Mn	mg/L	0.21	0.22	0.23	0.20	0.17
Mo	mg/L	0.012	0.023	0.011	0.002	<0.002
Na	mg/L	120.	120.	120.	90.	96.
Ni	mg/L	0.022	0.047	0.033	0.030	0.020
Pb	mg/L	0.001	<0.001	0.001	0.018	<0.004
Se	mg/L	0.007	0.020	0.003	0.022	0.017
V	mg/L	0.012	0.043	0.054	0.030	<0.003
Zn	mg/L	0.15	0.14	0.11	0.041	0.22
F	mg/L	15.	12.	14.	11.	11.
Cl	mg/L	180.	220.	160.	120.	190.
HCO ₃	mg/L	378.	299.	401.	400.	391.
CO ₃	mg/L	-	26.	<6.	<3.	<10.
NH ₃ (N)	mg/L	1.	<0.1	1.	0.2	1.
NO ₂ (N)	mg/L	<0.1	0.40	<0.1	0.4	<0.1
NO ₃ (N)	mg/L	7.	3.	5.	10.	6.
SO ₄	mg/L	180.	190.	150.	120.	150.
TDS	mg/L	934.	1010.	885.	820.	920.
TSS	mg/L	2.	<2.	<2.	5.	<2.
pH	units	6.9	7.2	7.2	7.5	7.1
Sp. Cond.	μmhos	1461.	1650.	1450.	1230.	1450.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.216	0.14	0.04	0.06	0.16
Ra-228	pCi/L	<1.9	<3.1	<2.	<1.9	<1.4
Th-230	pCi/L	0.039	1.87	0.050	0.026	0.021
Th-232	pCi/L	0.010	0.005	0.012	0.004	0.003
U-238	mg/L	0.099	0.001	0.003	0.003	0.001

Table C.7. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	0.073	<0.020	<0.02
Al	mg/L	<0.05	<0.2	0.33	0.087	0.057
As	mg/L	0.003	<0.1	0.14	<0.11	<0.11
B	mg/L	0.15	0.32	0.26	0.31	0.19
Ba	mg/L	<0.001	<0.02	<0.02	<0.013	0.013
Ca	mg/L	120.	140.	120.	130.	120.
Cd	mg/L	<0.002	<0.01	0.013	<0.007	<0.007
Co	mg/L	<0.006	<0.04	0.04	<0.011	<0.011
Cr	mg/L	<0.001	<0.03	0.055	<0.026	<0.026
Cu	mg/L	<0.001	<0.03	0.056	0.034	<0.017
Fe	mg/L	<0.008	<0.05	<0.05	<0.024	<0.024
Hg	mg/L	<0.00008	0.00011	<0.0001	<0.00030	0.00047
K	mg/L	0.8	1.8	0.88	1.9	1.3
Mg	mg/L	46.	49.	51.	53.	49.
Mn	mg/L	0.16	0.13	0.11	0.12	0.11
Mo	mg/L	0.009	0.019	0.037	<0.018	<0.018
Na	mg/L	96.	70.	55.	74.	78.
Ni	mg/L	0.017	<0.08	<0.08	0.041	<0.038
Pb	mg/L	<0.001	<0.1	0.20	<0.068	<0.068
Se	mg/L	0.007	0.10	0.19	0.10	<0.10
V	mg/L	<0.003	<0.038	0.069	0.025	0.029
Zn	mg/L	0.093	0.12	0.096	0.095	0.11
F	mg/L	13.	10.	10.	10.	13.
Cl	mg/L	150.	110.	75.	130.	150.
HCO ₃	mg/L	390.	380.	430.	370.	390.
TOC	mg/L	-	-	-	-	4.
NH ₃ (N)	mg/L	<1.	<0.1	0.1	0.3	<0.1
NO ₂ (N)	mg/L	3.5	<0.1	0.6	0.04	<0.01
NO ₃ (N)	mg/L	4.	9.	8.	7.	<1.
SO ₄	mg/L	110.	110.	87.	140.	150.
TDS	mg/L	770.	710.	680.	790.	770.
TSS	mg/L	<2.	4.	2.	18.	3.
pH	units	7.5	7.1	7.	6.8	6.9
Sp. Cond.	µmhos	1240.	1150.	1060.	1480.	2100.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.012	0.13	0.06	0.19	0.04
Ra-228	pCi/L	<1.7	<2.	-	-	0.27(s)
Th-230	pCi/L	0.022	0.025	0.025	-	0.021
Th-232	pCi/L	0.008	0.006	0.008	-	0.015
U-238	mg/L	0.006	0.002	0.01	0.002	0.010

Table C.7. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	<0.020	<0.002
Al	mg/L	<0.008	0.049	<0.11	0.81
As	mg/L	<0.11	<0.11	<0.11	<0.057
B	mg/L	0.18	0.17	0.19	0.64
Ba	mg/L	<0.013	<0.013	0.011	0.18
Ca	mg/L	110.	100.	120.	120.
Cd	mg/L	0.008	<0.007	<0.015	<0.002
Co	mg/L	0.017	<0.011	<0.011	<0.006
Cr	mg/L	<0.026	<0.026	0.039	<0.001
Cu	mg/L	<0.017	<0.017	0.016	<0.001
Fe	mg/L	0.029	<0.024	<0.033	0.020
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.005
K	mg/L	0.78	0.93	1.1	8.
Mg	mg/L	44.	44.	50.	48.
Mn	mg/L	0.11	0.071	0.067	0.079
Mo	mg/L	<0.018	<0.018	<0.018	<0.020
Na	mg/L	69.	47.	79.	89.
Ni	mg/L	<0.038	<0.038	<0.069	0.024
Pb	mg/L	<0.068	<0.068	0.076	<0.06
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	0.008	0.009	0.027	0.060
Zn	mg/L	0.24	0.22	0.083	0.091
F	mg/L	14.	11.	9.	11.
Cl	mg/L	91.	63.	95.	95.
HCO ₃	mg/L	390.	380.	380.	380.
TOC	mg/L	18.	7.2	17.	6.2
NH ₃ (N)	mg/L	0.2	<0.1	<0.1	0.2
NO ₂ (N)	mg/L	0.05	0.04	-	-
NO ₃ (N)	mg/L	5.	6.	5.	5.
SO ₄	mg/L	130.	80.	200.	94
TDS	mg/L	700.	580.	700.	700.
TSS	mg/L	<2.	3.	<2.	<2.
pH	units	7.0	7.0	7.0	7.1
Sp.Cond.	μmhos	1540.	1120.	1260.	1050.
Ra-224	pCi/L	0.08	0.01	0.09	0.04
Ra-226	pCi/L	0.15	0.	0.	0.02
Ra-228	pCi/L	0.02(s)	0.17	0.07	0.23
Th-230	pCi/L	0.046	0.025	0.069	0.007
Th-232	pCi/L	0.019	0.007	0.005	0.007
U-238	mg/L	0.002	0.001	0.002	0.005

Source: Munson and Lambert (1981-1985).

Table C.8. Concentrations of Chemical and Radiological Parameters at Different Times in the KM Wells on the West Chicago Site, Well KM-1

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	0.001	<0.002	<0.002	<0.002	<0.002
Al	mg/L	0.067	0.06	0.010	0.021	<0.050
As	mg/L	0.071	0.077	<0.001	0.27	0.020
B	mg/L	0.24	0.25	<0.009	0.22	0.22
Ba	mg/L	0.044	0.21	0.12	0.16	0.093
Ca	mg/L	190.	200.	210.	200.	200.
Cd	mg/L	<0.001	0.008	<0.002	<0.002	<0.002
Co	mg/L	0.008	<0.006	<0.006	<0.006	<0.006
Cr	mg/L	<0.001	0.029	<0.001	0.014	<0.001
Cu	mg/L	<0.001	0.008	<0.001	0.035	<0.001
Fe	mg/L	1.7	0.76	0.50	0.58	0.49
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	6.8	48.	6.4	7.3	6.8
Mg	mg/L	130.	120.	120.	110.	120.
Mn	mg/L	0.068	0.083	0.080	0.087	0.065
Mo	mg/L	0.020	0.021	<0.002	0.004	<0.002
Na	mg/L	540.	450.	550.	530.	510.
Ni	mg/L	0.16	0.17	0.16	0.17	0.16
Pb	mg/L	0.003	<0.001	<0.001	0.042	<0.004
Se	mg/L	0.002	0.22	<0.001	0.15	0.091
V	mg/L	0.009	0.19	0.010	0.021	<0.003
Zn	mg/L	0.037	0.11	0.068	0.089	0.12
F	mg/L	0.50	<0.5	0.44	<1.	0.57
Cl	mg/L	270.	280.	270.	290.	250.
HCO ₃	mg/L	554.	485.	568.	570.	572.
CO ₃	mg/L	-	13.	<6.	<3.	<10.
NH ₃ (N)	mg/L	2.	<0.1	<0.1	0.3	1.
NO ₂ (N)	mg/L	<0.1	0.71	<0.1	0.1	0.12
NO ₃ (N)	mg/L	<1.	1.	<1.	1.	<1.
SO ₄	mg/L	1290.	1320.	1320.	1280.	1240.
TDS	mg/L	2813.	2640.	2705.	2720.	2730.
TSS	mg/L	-	3660.	370.	200.	64.
pH	units	7.3	7.5	7.5	7.5	7.6
Sp. Cond.	µmhos	4142.	3560.	3380.	3190.	3650.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	-	4.42	0.48	0.62	0.47
Ra-228	pCi/L	-	<3.1	<2.	<0.9	<2.1
Th-230	pCi/L	-	0.065	0.025	0.017	0.025
Th-232	pCi/L	-	0.006	0.012	0.004	0.006
U-238	mg/L	0.003	0.01	0.01	0.004	0.003

Table C.8. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	0.10	0.031	0.024
Al	mg/L	<0.05	<0.2	0.42	0.22	0.11
As	mg/L	0.001	<0.1	0.20	<0.11	<0.11
B	mg/L	0.19	0.35	0.24	0.35	0.20
Ba	mg/L	<0.001	0.021	0.027	0.021	0.022
Ca	mg/L	200.	210.	200.	190.	170.
Cd	mg/L	<0.002	0.010	0.020	<0.007	<0.007
Co	mg/L	<0.006	<0.04	0.056	0.019	<0.011
Cr	mg/L	0.008	0.030	0.080	0.045	0.035
Cu	mg/L	<0.001	<0.03	0.074	0.043	0.019
Fe	mg/L	0.60	0.72	0.77	0.96	0.36
Hg	mg/L	0.00012	0.00023	<0.0001	<0.00030	0.00031
K	mg/L	6.2	6.2	6.3	7.4	5.8
Mg	mg/L	120.	120.	120.	120.	110.
Mn	mg/L	0.074	0.081	0.087	0.074	0.066
Mo	mg/L	0.019	0.029	0.063	0.026	<0.018
Na	mg/L	500.	500.	480.	460.	460.
Ni	mg/L	0.16	0.19	0.27	0.19	0.13
Pb	mg/L	0.001	<0.1	0.33	0.13	<0.068
Se	mg/L	0.001	<0.1	0.28	0.1	0.10
V	mg/L	<0.003	<0.04	0.085	0.032	0.014
Zn	mg/L	0.090	0.14	0.12	0.71	0.087
F	mg/L	<1.	3.1	1.	1.	<1.
Cl	mg/L	240.	280.	240.	230.	190.
HCO ₃	mg/L	570.	505.	620.	550.	560.
TOC	mg/L	-	-	-	-	14.
NH ₃ (N)	mg/L	<1.	<0.1	1.2	1.	<0.1
NO ₂ (N)	mg/L	1.	0.6	2.	1.	0.50
NO ₃ (N)	mg/L	<1.	6.	3.	1.	<1.
SO ₄	mg/L	1100.	1180.	1090.	1170.	1030.
TDS	mg/L	2490.	2670.	2550.	2440.	2370.
TSS	mg/L	31.	38.	40.	1016.	54.
pH	units	7.9	7.6	7.3	7.2	7.4
Sp. Cond.	µmhos	3550.	3510.	3460.	3890.	3150.
Ra-224	pCi/L	0.03	0.14	0.34	0.71	-
Ra-226	pCi/L	0.13	0.41	2.81	1.25	0.63
Ra-228	pCi/L	<3.	<3.	-	-	1.08
Th-230	pCi/L	0.077	0.028	0.017	-	0.006
Th-232	pCi/L	0.010	0.007	0.003	-	0.003
U-238	mg/L	0.003	0.0065	0.002	0.002	0.015

Table C.8. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	-	0.026	<0.002
Al	mg/L	<0.008	-	<0.11	0.66
As	mg/L	<0.11	-	<0.11	<0.06
B	mg/L	0.23	-	0.24	0.30
Ba	mg/L	0.017	-	0.016	0.17
Ca	mg/L	180.	170.	200.	180.
Cd	mg/L	0.010	-	0.018	<0.002
Co	mg/L	<0.011	-	0.030	<0.006
Cr	mg/L	<0.026	-	0.030	<0.001
Cu	mg/L	<0.017	-	0.018	<0.001
Fe	mg/L	0.20	-	3.7	4.8
Hg	mg/L	<0.0005	-	<0.0005	<0.0005
K	mg/L	5.2	6.2	5.6	20.
Mg	mg/L	94.	100.	110.	106.
Mn	mg/L	0.077	-	0.076	0.086
Mo	mg/L	0.020	-	0.034	0.008
Na	mg/L	390.	430.	390.	460.
Ni	mg/L	0.19	-	0.18	0.11
Pb	mg/L	<0.068	-	0.14	<0.08
Se	mg/L	<0.10	-	<0.10	<0.08
V	mg/L	<0.005	-	0.036	<0.003
Zn	mg/L	0.22	-	0.029	0.055
F	mg/L	<1.	-	<1.	<1.
Cl	mg/L	250.	260.	230.	190.
HCO ₃	mg/L	520.	550.	470.	560.
TOC	mg/L	17.	-	12.	38.
NH ₃ (N)	mg/L	1.3	-	<0.1	<0.1
NO ₂ (N)	mg/L	0.50	-	-	-
NO ₃ (N)	mg/L	<1.	2.	2.	<1.
SO ₄	mg/L	1040.	900.	880.	800.
TDS	mg/L	2220.	-	2220.	2200.
TSS	mg/L	28.	-	12.	10.
pH	units	7.7	7.1	7.1	7.2
Sp. Cond.	μmhos	3580.	-	3150.	3190.
Ra-224	pCi/L	3.02	-	-	-
Ra-226	pCi/L	0.55	-	0.05	0.06
Ra-228	pCi/L	0.68	-	0.59	0.51
Th-230	pCi/L	0.029	-	0.047	0.402
Th-232	pCi/L	0.010	-	0.005	0.006
U-238	mg/L	0.003	-	0.003	0.003

Source: Munson and Lambert (1981-1985).

Table C.9. Concentrations of Chemical and Radiological Parameters at Different Times in the KM Wells on the West Chicago Site, Well KM-2

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	0.010	0.007	<0.002
Al	mg/L	0.051	0.05	0.071	0.3	0.16
As	mg/L	0.005	0.007	0.001	0.02	0.004
B	mg/L	0.23	0.26	0.075	0.21	0.20
Ba	mg/L	0.14	0.35	0.28	0.32	0.13
Ca	mg/L	100.	97.	93.	90.	96.
Cd	mg/L	<0.001	<0.008	<0.002	0.003	<0.002
Co	mg/L	0.002	<0.006	<0.006	0.007	<0.006
Cr	mg/L	<0.001	0.007	0.002	0.023	0.003
Cu	mg/L	<0.001	<0.001	<0.001	0.033	<0.001
Fe	mg/L	0.53	0.16	0.11	0.13	0.13
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	3.2	27.	2.7	3.5	3.2
Mg	mg/L	81.	76.	72.	74.	75.
Mn	mg/L	0.034	0.015	0.025	0.031	0.02
Mo	mg/L	0.004	0.007	0.003	0.009	0.002
Na	mg/L	120.	104.	120.	120.	120.
Ni	mg/L	0.042	0.038	0.040	0.053	0.041
Pb	mg/L	0.002	<0.001	<0.001	0.017	<0.004
Se	mg/L	0.001	0.004	0.001	0.019	0.016
V	mg/L	0.002	<0.003	0.006	0.05	<0.003
Zn	mg/L	0.017	<0.003	0.009	0.032	0.073
F	mg/L	0.81	1.8	0.74	<1.	0.84
Cl	mg/L	73.	89.	85.	85.	79.
HCO ₃	mg/L	444.	316.	415.	420.	420.
CO ₃	mg/L	-	22.	<6.	<3.	<10.
NH ₃ (N)	mg/L	2.	<0.1	<0.1	1.2	0.9
NO ₂ (N)	mg/L	<0.1	0.06	<0.1	0.2	0.28
NO ₃ (N)	mg/L	<1.	<1.	<1.	1.	<1.
SO ₄	mg/L	360.	380.	370.	330.	340.
TDS	mg/L	971.	830.	926.	910.	960.
TSS	mg/L	-	207.	140.	95.	32.
pH	units	7.4	7.8	7.9	7.8	7.8
Sp. Cond.	umhos	1482.	1450.	1320.	1280.	1440.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	-	0.62	0.37	0.87	0.53
Ra-228	pCi/L	-	<2.3	<1.5	<1.5	<2.8
Th-230	pCi/L	-	0.351	0.109	0.031	0.030
Th-232	pCi/L	-	0.003	0.014	0.003	0.001
U-238	mg/L	0.010	0.002	0.003	0.003	0.002

Table C.9. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	0.094	<0.020	0.022
Al	mg/L	<0.05	<0.2	0.39	0.097	0.082
As	mg/L	<0.001	<0.1	0.19	<0.11	<0.11
B	mg/L	0.24	0.33	0.25	0.37	0.23
Ba	mg/L	0.12	0.13	0.13	0.093	0.13
Ca	mg/L	97.	100.	98.	99.	89.
Cd	mg/L	<0.002	<0.1	0.016	<0.007	<0.007
Co	mg/L	<0.006	<0.04	0.044	<0.011	<0.011
Cr	mg/L	0.003	<0.03	0.077	<0.026	<0.026
Cu	mg/L	<0.001	<0.03	0.067	0.029	0.022
Fe	mg/L	11.	0.14	0.17	0.067	0.16
Hg	mg/L	<0.00008	<0.001	<0.0001	<0.00030	<0.00031
K	mg/L	2.6	2.9	2.9	4.4	2.8
Mg	mg/L	71.	73.	74.	75.	73.
Mn	mg/L	0.022	0.029	0.036	0.030	0.036
Mo	mg/L	0.014	0.023	0.054	0.030	0.023
Na	mg/L	110.	110.	120.	120.	110.
Ni	mg/L	0.039	<0.08	0.12	0.076	0.060
Pb	mg/L	<0.001	0.11	0.30	<0.068	<0.068
Se	mg/L	0.005	<0.1	0.25	<0.10	<0.10
V	mg/L	<0.003	<0.04	0.077	0.021	0.009
Zn	mg/L	0.026	0.14	0.10	0.14	0.087
F	mg/L	<1.	<1.	<1.	<1.	<1.
Cl	mg/L	73.	92.	85.	90.	73.
HCO ₃	mg/L	410.	365.	460.	410.	420.
TOC	mg/L	-	-	-	-	15.
NH ₃ (N)	mg/L	<1.	<0.1	1.1	0.8	<0.1
NO ₂ (N)	mg/L	<0.1	0.7	4.	8.	0.40
NO ₃ (N)	mg/L	<1.	8.	2.	<1.	<1.
SO ₄	mg/L	260.	300.	320.	300.	350.
TDS	mg/L	900.	900.	940.	880.	960.
TSS	mg/L	25.	229.	25.	412.	64.
pH	units	7.9	7.8	7.7	7.4	7.6
Sp. Cond.	umhos	1340.	1460.	1360.	1530.	1360.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.39	0.91	0.80	5.03	0.05
Ra-228	pCi/L	<2.6	<2.0	-	-	0.59(s)
Th-230	pCi/L	0.017	0.027	0.032	-	0.006
Th-232	pCi/L	0.013	0.006	0.005	-	0.003
U-238	mg/L	<0.002	0.01	0.002	0.002	0.015

Table C.9. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	<0.020	<0.002
Al	mg/L	<0.008	<0.008	<0.11	0.6
As	mg/L	<0.11	<0.11	<0.11	<0.06
B	mg/L	0.23	0.24	0.24	0.29
Ba	mg/L	0.15	0.14	0.14	0.11
Ca	mg/L	94.	90.	110.	99.
Cd	mg/L	<0.007	<0.007	<0.015	<0.002
Co	mg/L	<0.011	<0.011	0.016	<0.006
Cr	mg/L	<0.026	<0.026	<0.026	<0.006
Cu	mg/L	<0.017	<0.017	<0.015	<0.001
Fe	mg/L	0.047	0.18	0.042	2.1
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.0005
K	mg/L	2.4	3.2	2.9	12.
Mg	mg/L	68.	71.	79.	77.
Mn	mg/L	0.030	0.022	0.025	0.018
Mo	mg/L	<0.018	<0.018	0.026	0.010
Na	mg/L	110.	120.	120.	140.
Ni	mg/L	<0.038	<0.038	<0.069	0.030
Pb	mg/L	<0.068	<0.068	0.077	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	<0.005	0.006	<0.025	<0.003
Zn	mg/L	0.18	0.25	0.018	0.047
F	mg/L	<1.	<1.	<1.	<1.
Cl	mg/L	82.	88.	130.	79.
HCO ₃	mg/L	420.	410.	390.	430.
TOC	mg/L	8.0	12.	11.	12.
NH ₃ (N)	mg/L	0.5	<0.1	0.6	<0.1
NO ₂ (N)	mg/L	1.4	0.90	-	-
NO ₃ (N)	mg/L	<1.	<1.	<1.	1.
SO ₄	mg/L	270.	280.	340.	260.
TDS	mg/L	980.	900.	890.	960.
TSS	mg/L	19.	21.	19.	5.
pH	units	7.9	7.7	7.6	7.7
Sp. Cond.	µmhos	1540.	1640.	1470.	1480.
Ra-224	pCi/L	3.49	-	-	-
Ra-226	pCi/L	0.84	0.21	0.	0.30
Ra-228	pCi/L	-	0.40	0.55	0.14
Th-230	pCi/L	0.022	0.364	0.045	0.086
Th-232	pCi/L	0.007	0.008	0.004	0.009
U-238	mg/L	0.001	0.006	0.002	<0.002

Source: Munson and Lambert (1981-1985).

Table C.10. Concentrations of Chemical and Radiological Parameters at Different Times in the KM Wells on the West Chicago Site, Well KM-4

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	0.006	0.006	0.007
Al	mg/L	0.018	0.19	<0.050	0.29	0.31
As	mg/L	0.005	<0.006	0.001	0.018	0.006
B	mg/L	0.20	0.25	<0.009	0.20	0.22
Ba	mg/L	0.039	0.26	0.15	0.22	0.10
Ca	mg/L	120.	120.	110.	120.	130.
Cd	mg/L	<0.001	<0.002	0.002	<0.002	<0.002
Co	mg/L	0.002	<0.006	<0.006	0.013	0.006
Cr	mg/L	<0.001	0.014	0.002	0.025	0.019
Cu	mg/L	0.003	<0.001	0.002	0.04	0.026
Fe	mg/L	0.063	0.024	0.040	0.034	0.26
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	0.001
K	mg/L	3.8	26.	3.6	4.	5.2
Mg	mg/L	74.	70.	60.	62.	68.
Mn	mg/L	0.26	0.23	0.28	0.25	0.23
Mo	mg/L	0.001	0.040	<0.002	<0.002	<0.002
Na	mg/L	110.	93.	120.	100.	140.
Ni	mg/L	0.015	0.025	0.019	0.03	0.036
Pb	mg/L	0.002	<0.001	<0.001	0.011	<0.004
Se	mg/L	0.005	0.003	<0.001	0.012	0.010
V	mg/L	0.002	0.005	0.010	0.057	0.026
Zn	mg/L	0.022	0.050	0.072	0.021	0.12
F	mg/L	0.80	0.8	0.75	<1.	0.7
Cl	mg/L	180.	170.	180.	160.	180.
HCO ₃	mg/L	457.	364.	469.	460.	471.
CO ₃	mg/L	-	41.	<6.	<3.	<10.
NH ₃ (N)	mg/L	<1.	<0.1	<0.1	0.1	0.7
NO ₂ (N)	mg/L	<0.1	0.04	<0.1	<0.1	0.34
NO ₃ (N)	mg/L	1.	2.	<1.	2.	<1.
SO ₄	mg/L	200.	230.	220.	140.	280.
TDS	mg/L	954.	867.	960.	860.	1090.
TSS	mg/L	-	87.	400.	-	10.
pH	units	7.4	7.6	7.5	8.	7.5
Sp. Cond.	umhos	1504.	1480.	1470.	1340.	1660.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	-	0.43	0.27	-	0.25
Ra-228	pCi/L	-	<2.5	<2.	<1.6	<1.6
Th-230	pCi/L	-	0.108	0.121	0.045	0.046
Th-232	pCi/L	-	0.006	0.010	0.011	0.007
U-238	mg/L	0.078	0.007	0.004	0.003	0.003

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Table C.10. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	0.095	0.024	0.026
Al	mg/L	<0.05	<0.2	0.40	0.072	0.14
As	mg/L	0.001	<0.1	0.20	<0.11	<0.11
B	mg/L	0.16	0.33	0.22	0.31	0.18
Ba	mg/L	0.006	0.035	0.044	0.035	0.031
Ca	mg/L	140.	150.	140.	140.	130.
Cd	mg/L	<0.002	<0.01	0.018	<0.007	<0.007
Co	mg/L	<0.006	<0.04	0.057	0.018	<0.011
Cr	mg/L	0.004	<0.03	0.078	<0.026	<0.026
Cu	mg/L	<0.001	<0.03	0.078	0.033	0.040
Fe	mg/L	0.035	0.059	0.092	<0.024	0.026
Hg	mg/L	<0.00009	<0.001	0.00014	<0.00030	0.00041
K	mg/L	4.	4.4	4.2	5.	4.0
Mg	mg/L	66.	70.	67.	70.	67.
Mn	mg/L	0.24	0.28	0.30	0.28	0.27
Mo	mg/L	0.005	<0.02	0.050	<0.018	<0.018
Na	mg/L	130.	150.	150.	150.	130.
Ni	mg/L	0.027	<0.08	0.12	0.064	0.054
Pb	mg/L	<0.001	0.12	0.32	0.085	<0.068
Se	mg/L	0.009	<0.1	0.24	<0.10	<0.10
V	mg/L	<0.003	<0.04	0.083	0.019	0.027
Zn	mg/L	0.13	0.12	0.091	0.077	0.096
F	mg/L	<1.	<1.	<1.	<1.	<1.
Cl	mg/L	170.	230.	150.	190.	160.
HCO ₃	mg/L	460.	425.	510.	460.	460.
TOC	mg/L	-	-	-	-	8.
NH ₃ (N)	mg/L	<1.	<0.1	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	0.1	0.4	1.2	0.5	0.40
NO ₃ (N)	mg/L	<1.	7.	3.	<1.	<1.
SO ₄	mg/L	200.	302.	230.	250.	240.
TDS	mg/L	860.	1100.	1080.	1050.	1010.
TSS	mg/L	33.	26.	17.	29.	32.
pH	units	7.8	7.6	7.7	7.2	7.3
Sp. Cond.	µmhos	1580.	1620.	1580.	1770.	1680.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.24	0.15	0.91	1.29	0.82
Ra-228	pCi/L	<2.	<2.	-	-	0.57(s)
Th-230	pCi/L	0.007	0.037	0.012	-	0.009
Th-232	pCi/L	0.004	0.005	0.003	-	0.003
U-238	mg/L	0.002	0.0005	0.003	0.002	0.009

Table C.10. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.033	<0.002
Al	mg/L	<0.008	0.010	<0.11	0.54
As	mg/L	<0.11	<0.11	<0.11	<0.06
B	mg/L	0.20	0.20	0.21	0.25
Ba	mg/L	0.028	0.033	0.032	0.18
Ca	mg/L	120.	120.	160.	130.
Cd	mg/L	0.015	<0.007	0.020	<0.004
Co	mg/L	<0.011	<0.011	0.037	<0.006
Cr	mg/L	<0.026	<0.026	0.032	<0.001
Cu	mg/L	<0.017	<0.017	0.024	<0.001
Fe	mg/L	<0.024	<0.024	<0.033	0.035
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.0005
K	mg/L	3.7	4.0	3.7	12.
Mg	mg/L	61.	65.	67.	66.
Mn	mg/L	0.30	0.25	0.27	0.26
Mo	mg/L	<0.018	<0.018	0.026	<0.001
Na	mg/L	130.	120.	103.	140.
Ni	mg/L	0.055	<0.038	<0.069	0.018
Pb	mg/L	<0.068	<0.068	0.16	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	<0.005	0.009	0.038	<0.003
Zn	mg/L	0.26	0.20	0.039	<0.003
F	mg/L	6.9	<1.	<1.	<1.
Cl	mg/L	160.	180.	160.	140.
HCO ₃	mg/L	470.	460.	420.	460.
TOC	mg/L	3.7	12.	74.	8.6
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	0.1	0.04	-	-
NO ₃ (N)	mg/L	<1.	<1.	<1.	<1.
SO ₄	mg/L	250.	190.	210.	180.
TDS	mg/L	960.	930.	930.	950.
TSS	mg/L	78.	4.	<2.	2.
pH	units	7.8	7.2	7.2	7.2
Sp. Cond.	μmhos	1790.	1660.	1580.	1530.
Ra-224	pCi/L	3.89	-	-	0.07
Ra-226	pCi/L	1.21	0.08	0.02	0.04
Ra-228	pCi/L	0.64(s)	0.23	0.42	0.34
Th-230	pCi/L	0.023	0.062	0.060	0.058
Th-232	pCi/L	0.023	0.004	0.003	0.003
U-238	mg/L	0.004	0.009	0.005	0.003

Source: Munson and Lambert (1981-1985).

Table C.11. Concentrations of Chemical and Radiological Parameters at Different Times in the KM Wells on the West Chicago Site, Well KM-5

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	0.005	<0.002	<0.002
Al	mg/L	0.002	<0.05	<0.050	0.29	0.15
As	mg/L	0.014	<0.006	0.002	0.021	0.004
B	mg/L	-	0.26	<0.009	0.24	0.18
Ba	mg/L	0.053	0.27	0.14	0.21	0.12
Ca	mg/L	130.	120.	100.	120.	130.
Cd	mg/L	<0.001	<0.002	<0.002	0.003	<0.002
Co	mg/L	0.007	<0.006	<0.006	0.011	<0.006
Cr	mg/L	<0.001	0.024	0.002	0.023	0.004
Cu	mg/L	<0.001	0.017	<0.001	0.042	<0.001
Fe	mg/L	0.48	0.46	0.048	0.24	0.23
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	4.3	3.6	3.6	4.6	4.4
Mg	mg/L	77.	67.	69.	69.	70.
Mn	mg/L	0.15	0.11	0.13	0.13	0.12
Mo	mg/L	0.004	0.013	<0.002	0.003	<0.002
Na	mg/L	110.	110.	120.	120.	110.
Ni	mg/L	0.024	0.028	0.025	0.04	0.029
Pb	mg/L	<0.001	<0.001	0.001	0.021	<0.004
Se	mg/L	0.003	<0.001	0.001	0.02	0.012
V	mg/L	<0.001	0.024	0.06	0.053	<0.003
Zn	mg/L	0.044	0.021	0.04	0.032	0.075
F	mg/L	0.53	0.7	0.41	<1.	0.47
Cl	mg/L	-	140.	150.	150.	140.
HCO ₃	mg/L	-	323.	458.	470.	472.
CO ₃	mg/L	-	16.	<6.	<3.	<10.
NH ₃ (N)	mg/L	<1.	<0.1	<0.1	<0.1	0.5
NO ₂ (N)	mg/L	<0.1	0.03	<0.1	<0.1	0.19
NO ₃ (N)	mg/L	2.	<1.	<1.	1.	<1.
SO ₄	mg/L	-	270.	260.	260.	280.
TDS	mg/L	-	780.	990.	970.	1040.
TSS	mg/L	-	201.	46.	28.	15.
pH	units	-	7.6	7.6	7.8	7.6
Sp. Cond.	μmhos	-	1530.	1570.	1390.	1520.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	-	0.70	0.20	0.16	0.15
Ra-228	pCi/L	-	<5.2	<1.5	<2.	<3.
Th-230	pCi/L	-	0.051	0.028	0.032	0.014
Th-232	pCi/L	-	0.006	0.005	0.010	0.005
U-238	mg/L	0.005	0.005	0.004	0.002	0.003

Table C.11. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	0.096	<0.020	<0.020
Al	mg/L	<0.05	<0.2	0.39	0.087	0.073
As	mg/L	0.001	<0.1	0.18	<0.11	<0.11
B	mg/L	0.19	0.37	0.22	0.30	0.19
Ba	mg/L	0.003	0.033	0.042	0.037	0.039
Ca	mg/L	140.	140.	130.	130.	130.
Cd	mg/L	<0.002	<0.01	0.018	<0.007	<0.007
Co	mg/L	<0.006	<0.04	0.052	0.014	<0.011
Cr	mg/L	<0.001	<0.03	0.076	<0.026	<0.026
Cu	mg/L	<0.001	<0.03	0.067	0.030	0.019
Fe	mg/L	0.46	0.41	0.21	0.024	0.039
Hg	mg/L	<0.00008	0.00014	0.00024	0.00032	0.00041
K	mg/L	3.8	4.2	3.9	4.9	4.0
Mg	mg/L	67.	70.	74.	71.	70.
Mn	mg/L	0.13	0.14	0.15	0.13	0.14
Mo	mg/L	0.005	<0.02	0.045	<0.018	<0.018
Na	mg/L	110.	110.	120.	100.	100.
Ni	mg/L	0.023	<0.08	0.11	0.047	0.038
Pb	mg/L	0.001	<0.1	0.32	0.079	<0.068
Se	mg/L	0.001	<0.1	0.26	<0.10	<0.10
V	mg/L	<0.003	<0.04	0.079	0.016	0.011
Zn	mg/L	0.11	0.10	0.11	0.59	0.10
F	mg/L	<1.	<1.	<1.	<1.	<1.
Cl	mg/L	150.	150.	130.	170.	110.
HCO ₃	mg/L	470.	415.	510.	460.	460.
TOC	mg/L	-	-	-	-	10.
NH ₃ (N)	mg/L	<1.	<0.1	0.2	0.2	<0.1
NO ₂ (N)	mg/L	0.5	0.8	1.4	0.28	0.50
NO ₃ (N)	mg/L	<1.	4.	2.	1.	<1.
SO ₄	mg/L	270.	260.	220.	260.	260.
TDS	mg/L	1000.	950.	960.	940.	980.
TSS	mg/L	17.	27.	50.	21.	15.
pH	units	7.7	7.5	7.5	7.4	7.3
Sp. Cond.	µmhos	1490.	1510.	1520.	1770.	1470.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.33	1.05	1.06	1.26	0.71
Ra-228	pCi/L	<1.6	<1.5	-	-	0.65(s)
Th-230	pCi/L	0.039	0.022	0.015	-	0.015
Th-232	pCi/L	0.005	0.004	0.003	-	0.003
U-238	mg/L	<0.002	0.009	0.004	0.002	0.005

Table C.11. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.038	<0.002
Al	mg/L	<0.008	<0.008	<0.11	<0.05
As	mg/L	<0.11	<0.11	<0.11	<0.06
B	mg/L	0.19	0.19	0.21	0.21
Ba	mg/L	0.040	0.039	0.033	0.19
Ca	mg/L	130.	90.	160.	140.
Cd	mg/L	<0.007	<0.007	0.023	<0.002
Co	mg/L	<0.011	<0.011	0.038	<0.006
Cr	mg/L	<0.026	<0.026	0.039	<0.001
Cu	mg/L	<0.017	<0.017	0.021	<0.001
Fe	mg/L	0.037	<0.024	1.8	1.6
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.0005
K	mg/L	3.5	3.8	3.4	12.
Mg	mg/L	52.	68.	69.	69.
Mn	mg/L	0.15	<0.003	0.14	0.14
Mo	mg/L	<0.018	<0.018	0.033	<0.002
Na	mg/L	98.	110.	85.	120.
Ni	mg/L	<0.038	0.040	0.074	<0.003
Pb	mg/L	<0.068	<0.068	0.19	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	<0.005	<0.005	0.042	<0.003
Zn	mg/L	0.21	0.074	0.030	0.045
F	mg/L	<1.	<1.	<1.	<1.
Cl	mg/L	130.	150.	160.	120.
HCO ₃	mg/L	460.	470.	350.	470.
TOC	mg/L	0.4	42.	20.	5.
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	0.50	<0.01	-	1.
NO ₃ (N)	mg/L	<1.	<1.	6.	<1.
SO ₄	mg/L	250.	160.	240.	180.
TDS	mg/L	910.	830.	880.	920.
TSS	mg/L	7.	2.	<2.	1.
pH	units	7.8	7.2	7.1	7.3
Sp. Cond.	µmhos	1660.	1640.	1470.	1530.
Ra-224	pCi/L	1.51	0.01	-	0.14
Ra-226	pCi/L	0.38	0.13	0.13	0.15
Ra-228	pCi/L	0.79(s)	0.41	0.23	0.49
Th-230	pCi/L	0.009	0.078	0.072	0.105
Th-232	pCi/L	0.003	0.045	0.006	0.029
U-238	mg/L	0.005	0.007	0.004	0.003

Source: Munson and Lambert (1981-1985).

Table C.12. Concentrations of Chemical and Radiological Parameters at Different Times in the KM Wells on the West Chicago Site, Well KM-6

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	<0.002	<0.002	<0.002
Al	mg/L	0.067	<0.05	0.29	0.24	0.093
As	mg/L	0.15	0.002	0.001	0.012	<0.004
B	mg/L	0.18	0.18	<0.009	0.24	0.24
Ba	mg/L	0.045	<0.001	0.13	0.2	0.11
Ca	mg/L	140.	130.	110.	120.	130.
Cd	mg/L	<0.001	<0.002	<0.002	<0.002	<0.002
Co	mg/L	0.001	<0.006	<0.006	0.012	<0.006
Cr	mg/L	<0.001	0.002	<0.001	0.023	<0.001
Cu	mg/L	<0.001	<0.001	<0.001	0.045	<0.001
Fe	mg/L	0.25	0.19	0.070	0.09	0.026
Hg	mg/L	<0.001	<0.00009	<0.001	<0.001	<0.001
K	mg/L	3.9	4.2	3.7	4.5	4.
Mg	mg/L	78.	66.	65.	67.	66.
Mn	mg/L	0.25	0.21	0.26	0.23	0.24
Mo	mg/L	0.004	0.005	0.004	0.004	<0.002
Na	mg/L	140.	140.	140.	140.	120.
Ni	mg/L	0.040	0.027	0.028	0.044	0.017
Pb	mg/L	0.001	<0.001	0.002	0.013	<0.004
Se	mg/L	0.002	0.007	<0.001	0.016	0.006
V	mg/L	0.003	<0.003	<0.003	0.05	<0.003
Zn	mg/L	0.043	0.26	0.026	0.013	0.07
F	mg/L	1.01	<1.	0.97	<1.	0.77
Cl	mg/L	190.	210.	210.	200.	180.
HCO ₃	mg/L	457.	470.	455.	460.	465.
CO ₃	mg/L	-	<5.	<6.	<3.	<10.
NH ₃ (N)	mg/L	1.	<1.	<0.1	0.2	0.6
NO ₂ (N)	mg/L	<0.1	0.5	<0.1	0.2	0.39
NO ₃ (N)	mg/L	<1.	<1.	<1.	1.	<1.
SO ₄	mg/L	290.	300.	270.	250.	220.
TDS	mg/L	1107.	1030.	1053.	1000.	1050.
TSS	mg/L	-	270.	91.	40.	8.
pH	units	7.4	7.8	7.7	7.8	7.6
Sp. Cond.	umhos	1700.	1600.	1570.	1450.	1600.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	-	0.28	0.67	0.04	0.18
Ra-228	pCi/L	-	<0.5	<1.3	<2.2	<1.4
Th-230	pCi/L	-	0.033	0.048	0.041	0.019
Th-232	pCi/L	-	0.006	0.007	0.006	0.006
U-238	mg/L	0.004	0.002	0.004	0.002	0.004

Table C.12. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	<0.02	0.070	<0.020
Al	mg/L	<0.05	<0.2	<0.042	0.26	0.068
As	mg/L	0.002	<0.1	<0.11	0.19	<0.11
B	mg/L	0.18	0.30	0.29	0.23	0.20
Ba	mg/L	<0.001	0.028	0.033	0.034	0.030
Ca	mg/L	130.	140.	140.	140.	130.
Cd	mg/L	<0.002	<0.01	<0.007	0.015	<0.007
Co	mg/L	<0.006	<0.04	0.014	<0.04	<0.011
Cr	mg/L	0.002	<0.03	<0.026	0.049	<0.026
Cu	mg/L	<0.001	<0.03	0.024	0.050	0.030
Fe	mg/L	0.19	0.16	0.054	0.12	0.048
Hg	mg/L	<0.00009	<0.0001	0.00032	0.00017	0.00031
K	mg/L	4.2	4.	5.3	4.2	4.2
Mg	mg/L	66.	68.	70.	68.	68.
Mn	mg/L	0.21	0.24	0.25	0.26	0.24
Mo	mg/L	0.005	<0.02	<0.018	0.035	<0.018
Na	mg/L	140.	130.	140.	130.	130.
Ni	mg/L	0.027	<0.08	0.052	0.087	0.046
Pb	mg/L	<0.001	<0.1	<0.068	0.21	<0.068
Se	mg/L	0.007	<0.1	<0.10	0.20	<0.10
V	mg/L	<0.003	<0.04	0.012	0.057	0.019
Zn	mg/L	0.26	0.076	0.19	0.094	0.12
F	mg/L	<1.	<1.	<1.	<1.	<1.
Cl	mg/L	210.	180.	190.	170.	140.
HCO ₃	mg/L	470.	385.	470.	510.	460.
TOC	mg/L	<5.	<5.	<10.	<5.	8.
NH ₃ (N)	mg/L	<1.	<0.1	0.2	0.4	<0.1
NO ₂ (N)	mg/L	0.5	0.3	0.40	0.6	0.40
NO ₃ (N)	mg/L	<1.	4.	<1.	3.	<1.
SO ₄	mg/L	300.	265.	260.	240.	230.
TDS	mg/L	1030.	1020.	1010.	1060.	1010.
TSS	mg/L	270.	23.	300.	37.	216.
pH	units	7.8	7.8	7.4	7.6	7.5
Sp. Cond.	µmhos	1600.	1620.	1770.	1580.	1630.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.28	0.36	1.01	4.68	4.25
Ra-228	pCi/L	<0.5	<1.5	-	-	1.22(s)
Th-230	pCi/L	0.033	0.024	-	0.014	0.009
Th-232	pCi/L	0.006	0.003	-	0.011	0.003
U-238	mg/L	0.002	0.003	0.002	0.07	0.014

Table C.12. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.034	<0.002
Al	mg/L	<0.008	0.043	<0.11	0.46
As	mg/L	<0.11	<0.11	<0.11	<0.06
B	mg/L	0.21	0.20	0.22	0.25
Ba	mg/L	0.034	0.027	0.030	0.18
Ca	mg/L	140.	120.	160.	140.
Cd	mg/L	<0.007	<0.007	0.020	<0.002
Co	mg/L	<0.011	<0.011	0.031	<0.006
Cr	mg/L	<0.026	<0.026	0.037	<0.001
Cu	mg/L	<0.017	<0.017	0.020	<0.001
Fe	mg/L	0.044	1.5	22.	2.1
Hg	mg/L	<0.0005	0.0014	<0.0005	<0.0005
K	mg/L	3.8	3.9	3.5	8.4
Mg	mg/L	59.	64.	67.	68.
Mn	mg/L	0.27	0.22	0.25	0.25
Mo	mg/L	<0.018	<0.018	0.025	0.005
Na	mg/L	120.	130.	97.	140.
Ni	mg/L	<0.038	<0.038	<0.069	<0.003
Pb	mg/L	<0.068	<0.068	0.17	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	<0.005	0.008	0.037	<0.003
Zn	mg/L	0.18	0.56	0.031	<0.003
F	mg/L	5.9	<1.	<1.	<1.
Cl	mg/L	170.	200.	180.	150.
HCO ₃	mg/L	460.	460.	360.	470.
TOC	mg/L	6.0	7.9	17.	3.3
NH ₃ (N)	mg/L	0.3	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	1.4	<0.01	-	-
NO ₃ (N)	mg/L	<1.	<1.	<1.	<1.
SO ₄	mg/L	170.	210.	230.	170.
TDS	mg/L	980.	980.	920.	930.
TSS	mg/L	140.	5.	3.	10.
pH	units	7.6	7.2	7.1	7.3
Sp. Cond.	umhos	2050.	1760.	1580.	1590.
Ra-224	pCi/L	2.50	-	0.02	0.01
Ra-226	pCi/L	2.74	0.02	0.07	0.06
Ra-228	pCi/L	2.57(s)	0.32	0.21	0.32
Th-230	pCi/L	0.099	0.037	0.024	0.051
Th-232	pCi/L	0.063	0.005	0.003	0.030
U-238	mg/L	0.005	0.008	0.005	0.006

Source: Munson and Lambert (1981-1985).

Table C.13. Concentrations of Chemical and Radiological Parameters at Different Times in the KM Wells on the West Chicago Site, Well KM-7

Chemical Species	Unit	1981		1982		
		2nd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Ag	mg/L	<0.001	<0.002	<0.002	<0.002	<0.002
Al	mg/L	0.010	0.16	0.21	0.24	<0.05
As	mg/L	0.016	<0.007	0.002	0.23	<0.004
B	mg/L	0.18	0.26	<0.009	0.22	0.20
Ba	mg/L	0.038	0.22	0.14	0.22	0.14
Ca	mg/L	120.	110.	110.	120.	130.
Cd	mg/L	<0.001	<0.002	<0.002	0.003	<0.002
Co	mg/L	0.001	<0.006	<0.006	0.008	<0.006
Cr	mg/L	<0.001	0.019	<0.001	0.025	<0.001
Cu	mg/L	<0.001	<0.001	<0.001	0.028	<0.001
Fe	mg/L	0.085	0.045	0.092	0.041	0.02
Hg	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
K	mg/L	4.3	3.9	3.9	4.6	4.6
Mg	mg/L	75.	62.	52.	64.	64.
Mn	mg/L	0.20	0.18	0.21	0.21	0.19
Mo	mg/L	<0.001	0.005	<0.002	0.002	<0.002
Na	mg/L	80.	74.	74.	70.	73.
Ni	mg/L	0.010	0.021	0.010	0.025	0.006
Pb	mg/L	0.001	0.002	0.004	0.01	<0.004
Se	mg/L	0.004	0.003	<0.001	0.02	0.008
V	mg/L	0.001	0.008	<0.003	0.046	<0.003
Zn	mg/L	0.033	0.069	0.028	0.21	0.31
F	mg/L	0.51	1.	0.48	<1.	0.48
Cl	mg/L	120.	120.	120.	160.	130.
HCO ₃	mg/L	464.	283.	436.	470.	461.
CO ₃	mg/L	-	16.	<6.	<3.	<10.
NH ₃ (N)	mg/L	<1.	<0.1	<0.1	0.1	0.3
NO ₂ (N)	mg/L	<0.1	0.02	<0.1	<0.1	0.3
NO ₃ (N)	mg/L	2.	<1.	<1.	1.	<1.
SO ₄	mg/L	210.	200.	170.	190.	180.
TDS	mg/L	890.	635.	832.	790.	871.
TSS	mg/L	-	7551.	4500.	225.	150.
pH	units	7.4	7.5	7.6	7.9	7.6
Sp. Cond.	µmhos	1406.	1222.	1220.	1380.	1340.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	-	2.28	0.16	1.56	0.15
Ra-228	pCi/L	-	<2.5	<2.	<1.5	<1.9
Th-230	pCi/L	-	0.081	0.036	0.012	0.019
Th-232	pCi/L	-	0.012	0.011	0.006	0.009
U-238	mg/L	0.007	0.007	0.003	0.003	0.003

Table C.13. Continued

Chemical Species	Unit	1982	1983			
		4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.002	<0.03	0.060	<0.020	<0.020
Al	mg/L	<0.05	<0.2	0.20	<0.042	0.061
As	mg/L	<0.001	<0.1	0.11	<0.11	<0.11
B	mg/L	0.13	0.35	0.20	0.20	0.18
Ba	mg/L	0.006	0.035	0.041	0.044	0.043
Ca	mg/L	130.	130.	130.	130.	120.
Cd	mg/L	<0.002	<0.01	0.011	<0.007	<0.007
Co	mg/L	<0.006	<0.04	<0.04	<0.011	<0.011
Cr	mg/L	<0.001	<0.03	0.041	<0.026	<0.026
Cu	mg/L	<0.001	<0.03	0.046	<0.017	0.024
Fe	mg/L	0.025	<0.05	0.13	<0.024	0.067
Hg	mg/L	<0.00009	<0.0001	0.00044	0.00038	0.00038
K	mg/L	3.8	4.	3.8	4.4	3.7
Mg	mg/L	62.	66.	63.	65.	65.
Mn	mg/L	0.19	0.20	0.23	0.19	0.21
Mo	mg/L	<0.002	<0.02	0.019	<0.018	<0.018
Na	mg/L	72.	67.	68.	70.	64.
Ni	mg/L	0.011	<0.08	<0.08	<0.038	<0.038
Pb	mg/L	<0.001	<0.1	0.18	<0.068	<0.068
Se	mg/L	0.003	<0.1	0.13	<0.10	<0.10
V	mg/L	<0.003	<0.04	0.045	<0.005	0.011
Zn	mg/L	0.034	0.058	0.10	0.072	0.094
F	mg/L	<1.	1.3	3.	<1.	<1.
Cl	mg/L	140.	140.	110.	140.	120.
HCO ₃	mg/L	460.	410.	500.	460.	460.
TOC	mg/L	<5.	<5.	<5.	<10.	7.
NH ₃ (N)	mg/L	<1.	<0.1	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	0.5	0.3	2.	0.70	1.4
NO ₃ (N)	mg/L	<1.	4.	2.	<1.	<1.
SO ₄	mg/L	210.	180.	180.	190.	180.
TDS	mg/L	800.	800.	820.	830.	820.
TSS	mg/L	41.	81.	118.	1426.	23.
pH	units	7.8	7.6	7.5	7.3	7.4
Sp. Cond.	µmhos	1340.	1400.	1260.	1530.	1360.
Ra-224	pCi/L	-	-	-	-	-
Ra-226	pCi/L	0.23	0.38	1.07	6.07	1.21
Ra-228	pCi/L	1.2	<3.3	-	-	0.93(s)
Th-230	pCi/L	0.056	0.055	0.017	-	0.009
Th-232	pCi/L	0.008	0.009	0.006	-	0.006
U-238	mg/L	0.003	0.007	0.004	0.002	0.005

Table C.13. Continued

Chemical Species	Unit	1984			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
Ag	mg/L	<0.020	<0.020	0.026	<0.002
Al	mg/L	<0.008	<0.008	<0.11	0.60
As	mg/L	<0.11	<0.11	<0.11	<0.057
B	mg/L	0.17	0.19	0.20	0.52
Ba	mg/L	0.041	0.037	0.037	0.21
Ca	mg/L	120.	120.	160.	130.
Cd	mg/L	<0.007	<0.007	0.016	<0.002
Co	mg/L	<0.011	<0.011	0.026	<0.006
Cr	mg/L	<0.026	<0.026	0.032	<0.001
Cu	mg/L	<0.017	<0.017	0.017	<0.001
Fe	mg/L	<0.024	0.14	0.41	0.74
Hg	mg/L	<0.0005	<0.0003	<0.0005	<0.0005
K	mg/L	3.0	4.0	3.5	12.
Mg	mg/L	59.	64.	66.	63.
Mn	mg/L	0.22	0.19	0.20	0.19
Mo	mg/L	<0.018	<0.018	0.021	0.015
Na	mg/L	69.	70.	59.	81.
Ni	mg/L	<0.038	<0.038	<0.069	<0.003
Pb	mg/L	<0.068	<0.068	0.14	<0.08
Se	mg/L	<0.10	<0.10	<0.10	<0.08
V	mg/L	<0.005	<0.005	<0.030	<0.003
Zn	mg/L	0.23	0.22	0.023	0.051
F	mg/L	<1.	<1.	<1.	<1.
Cl	mg/L	120.	130.	130.	110.
HCO ₃	mg/L	460.	450.	400.	460.
TOC	mg/L	13.	14.	22.	-
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	<0.1
NO ₂ (N)	mg/L	1.0	0.34	-	-
NO ₃ (N)	mg/L	<1.	<1.	1.	1.
SO ₄	mg/L	110.	220.	170.	130.
TDS	mg/L	780.	800.	740.	760.
TSS	mg/L	72.	4.	<2.	9.
pH	units	7.7	7.2	7.2	7.2
Sp. Cond.	µmhos	1540.	1380.	1310.	1300.
Ra-224	pCi/L	1.61	-	-	-
Ra-226	pCi/L	0.35	0.18	1.03	0.09
Ra-228	pCi/L	0.74(s)	0.31	1.94	0.33
Th-230	pCi/L	0.032	0.039	0.053	1.09
Th-232	pCi/L	0.024	0.003	0.006	0.021
U-238	mg/L	0.005	0.004	0.003	0.005

Source: Munson and Lambert (1981-1985).

Table C.14. Concentrations of Chemical and Radiological Parameters at Different Times in the F Wells on the West Chicago Site, Well F-1

Chemical Species	Unit	1982			1983
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.002	<0.002	<0.002	0.058
Al	mg/L	0.083	<0.05	<0.05	0.25
As	mg/L	0.049	0.004	0.002	0.11
B	mg/L	0.20	0.78	0.26	0.35
Ba	mg/L	0.17	0.11	<0.001	<0.02
Ca	mg/L	540.	260.	360.	560.
Cd	mg/L	0.003	<0.002	0.012	0.021
Co	mg/L	0.019	0.022	0.12	0.084
Cr	mg/L	0.042	0.007	0.018	0.077
Cu	mg/L	0.14	0.094	0.42	0.20
Fe	mg/L	0.47	0.52	2.8	0.84
Hg	mg/L	<0.001	<0.001	<0.00008	<0.0001
K	mg/L	7.3	4.8	4.6	6.1
Mg	mg/L	230.	140.	210.	280.
Mn	mg/L	0.82	0.47	0.95	0.93
Mo	mg/L	0.007	<0.002	0.014	0.032
Na	mg/L	110.	100.	100.	90.
Ni	mg/L	0.078	0.059	0.22	0.23
Pb	mg/L	0.02	0.004	<0.001	0.20
Se	mg/L	0.016	0.016	0.011	0.14
V	mg/L	0.066	<0.003	<0.003	0.052
Zn	mg/L	0.86	0.96	3.1	1.4
F	mg/L	4.	5.6	5.	4.1
Cl	mg/L	150.	100.	320.	210.
HCO ₃	mg/L	270.	287.	280.	240.
CO ₃	mg/L	<3.	<10.	<5.	<5.
NH ₃ (N)	mg/L	14.	4.5	5.	<0.1
NO ₂ (N)	mg/L	0.44	0.10	4.0	0.3
NO ₃ (N)	mg/L	520.	110.	240.	400.
SO ₄	mg/L	450.	720.	530.	620.
TDS	mg/L	3740.	1970.	2490.	3480.
TSS	mg/L	145.	18.	66.	10.
pH	units	6.8	7.0	7.4	6.9
Sp. Cond.	µmhos	4410.	2580.	3640.	4430.
Ra-224	pCi/L	-	-	-	-
Ra-226	pCi/L	1.21	11.9	0.10	0.03
Ra-228	pCi/L	0.02	0.011	<2.5	<3.4
Th-230	pCi/L	0.01	0.004	0.008	0.041
Th-232	pCi/L	0.002	0.005	0.004	0.005
U-238	mg/L	-	-	0.004	0.007

Table C.14. Continued

Chemical Species	Unit	1983			1984
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.11	0.058	0.044	<0.020
Al	mg/L	0.45	0.25	<0.042	<0.008
As	mg/L	0.23	<0.11	<0.11	<0.11
B	mg/L	0.40	0.58	0.35	0.38
Ba	mg/L	<0.02	<0.013	<0.013	<0.013
Ca	mg/L	440.	280.	230.	170.
Cd	mg/L	0.026	0.019	0.007	0.015
Co	mg/L	0.10	0.068	0.061	0.082
Cr	mg/L	0.10	0.033	<0.026	<0.026
Cu	mg/L	0.20	0.20	0.26	0.32
Fe	mg/L	0.69	1.2	1.5	1.1
Hg	mg/L	<0.0001	0.00030	0.00038	<0.0005
K	mg/L	5.9	6.5	5.7	4.0
Mg	mg/L	230.	160.	120.	88.
Mn	mg/L	0.75	0.62	0.59	0.68
Mo	mg/L	0.050	0.021	<0.018	<0.018
Na	mg/L	71.	56.	66.	53.
Ni	mg/L	0.22	0.14	0.083	0.12
Pb	mg/L	0.39	0.17	0.074	<0.068
Se	mg/L	0.26	<0.10	<0.10	<0.10
V	mg/L	0.099	0.042	0.007	0.005
Zn	mg/L	1.3	1.9	1.8	2.2
F	mg/L	4.	<1.	4.0	6.7
Cl	mg/L	190.	170.	150.	77.
HCO ₃	mg/L	280.	280.	270.	270.
TOC	mg/L	-	-	<17.	12.
NH ₃ (N)	mg/L	3.7	0.2	<0.1	0.1
NO ₂ (N)	mg/L	4.0	1.0	0.14	5.0
NO ₃ (N)	mg/L	250.	130.	78.	45.
SO ₄	mg/L	650.	460.	500.	320.
TDS	mg/L	2570.	1680.	1590.	1120.
TSS	mg/L	<2.	34.	6.0	9.
pH	units	6.8	6.8	6.9	7.0
Sp. Cond.	µmhos	3370.	2830.	2100.	2050.
Ra-224	pCi/L	0.05	0.07	0.00	0.16
Ra-226	pCi/L	0.07	0.07	0.02	0.11
Ra-228	pCi/L	<1.5	<2.0	-	0(s)
Th-230	pCi/L	0.016	0.009	0.004	0.018
Th-232	pCi/L	0.007	0.007	0.004	0.003
U-238	mg/L	0.004	0.002	0.010	0.003

Table C.14. Continued

Chemical Species	Unit	1984			1985
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.020	0.045	-	<0.004
Al	mg/L	0.052	0.19	60.	0.91
As	mg/L	<0.11	<0.11	<0.06	<0.12
B	mg/L	0.42	0.51	0.90	0.62
Ba	mg/L	<0.013	0.005	0.17	0.021
Ca	mg/L	350.	210.	190.	160.
Cd	mg/L	0.008	0.033	<0.002	<0.004
Co	mg/L	0.030	0.099	<0.006	<0.012
Cr	mg/L	0.034	0.049	<0.001	<0.010
Cu	mg/L	0.12	0.18	<0.001	<0.002
Fe	mg/L	0.15	2.0	0.12	0.054
Hg	mg/L	<0.0003	<0.0005	<0.005	<0.0005
K	mg/L	5.0	4.1	19.	4.5
Mg	mg/L	180.	95.	95.	78.
Mn	mg/L	0.060	0.57	0.23	0.088
Mo	mg/L	<0.018	0.034	0.019	<0.004
Na	mg/L	65.	39.	110.	290.
Ni	mg/L	0.14	0.12	0.024	<0.006
Pb	mg/L	<0.068	0.21	<0.08	<0.16
Se	mg/L	<0.10	<0.10	<0.08	<0.16
V	mg/L	0.013	0.050	0.046	<0.006
Zn	mg/L	1.4	1.5	0.14	0.037
F	mg/L	<1.	<1.	8.	8.
Cl	mg/L	260.	66.	160.	400.
HCO ₃	mg/L	260.	320.	400.	410.
TOC	mg/L	20.	18.	12.	14.
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	1.8
NO ₂ (N)	mg/L	6.6	-	-	-
NO ₃ (N)	mg/L	210.	36.	23.	32.
SO ₄	mg/L	530.	430.	290.	300.
TDS	mg/L	2146.	1040.	1230.	1540.
TSS	mg/L	13.	46.	60.	7.
pH	units	6.8	7.0	7.1	7.1
Sp. Cond.	umhos	3390.	1520.	1830.	2670.
Ra-224	pCi/L	-	-	-	-
Ra-226	pCi/L	-	0.01	-	0.1
Ra-228	pCi/L	0.70	0.02	0.44	0.12
Th-230	pCi/L	0.064	0.033	0.153	0.069
Th-232	pCi/L	0.024	0.003	0.012	0.005
U-238	mg/L	0.004	0.003	0.007	0.007

Source: Munson and Lambert (1981-1985).

Table C.15. Concentrations of Chemical and Radiological Parameters at Different Times in the F Wells on the West Chicago Site, Well F-2

Chemical Species	Unit	1982			1983
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.002	<0.002	<0.002	0.095
Al	mg/L	0.28	0.75	<0.05	1.1
As	mg/L	0.022	0.016	0.005	0.15
B	mg/L	0.36	0.48	N/A	2.8
Ba	mg/L	0.13	0.099	0.011	<0.02
Ca	mg/L	500.	550.	550.	670.
Cd	mg/L	<0.002	0.007	<0.002	0.021
Co	mg/L	0.01	0.022	<0.006	0.066
Cr	mg/L	0.017	0.047	0.007	0.078
Cu	mg/L	0.017	0.098	0.002	0.099
Fe	mg/L	0.71	0.048	0.074	1.1
Hg	mg/L	<0.001	0.001	<0.00008	<0.0001
K	mg/L	8.5	14.	8.0	8.6
Mg	mg/L	100.	68.	120.	110.
Mn	mg/L	0.79	0.36	0.68	0.76
Mo	mg/L	0.007	0.024	0.019	0.062
Na	mg/L	540.	570.	520.	500.
Ni	mg/L	0.078	0.073	0.11	0.19
Pb	mg/L	0.014	<0.004	<0.001	0.34
Se	mg/L	0.045	0.091	0.012	0.28
V	mg/L	0.027	0.13	<0.003	0.099
Zn	mg/L	1.4	1.2	2.1	3.0
F	mg/L	18.	17.	16.	18.
Cl	mg/L	190.	110.	240.	180.
HCO ₃	mg/L	420.	521.	310.	280.
CO ₃	mg/L	<3.	<10.	<5.	<5.
NH ₃ (N)	mg/L	5.4	3.3	4.	<0.1
NO ₂ (N)	mg/L	4.9	0.19	50.	0.5
NO ₃ (N)	mg/L	16.	26.	40.	120.
SO ₄	mg/L	2160.	2160.	2370.	2090.
TDS	mg/L	3920.	3920.	3990.	3950.
TSS	mg/L	2.	93.	N/A	17.
pH	units	6.9	7.0	7.4	6.9
Sp. Cond.	µmhos	3940.	4460.	4960.	4320.
Ra-224	pCi/L	-	-	-	-
Ra-226	pCi/L	0.57	3.10	N/A	0.52
Ra-228	pCi/L	2.7	<1.8	<1.9	<1.7
Th-230	pCi/L	0.66	0.018	0.079	0.066
Th-232	pCi/L	0.007	0.003	0.016	0.010
U-238	mg/L	2.0	2.7	0.14	0.93

Table C.15. Continued

Chemical Species	Unit	1983			1984
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.17	0.12	0.024	0.060
Al	mg/L	0.93	0.73	0.45	0.56
As	mg/L	0.34	0.22	<0.11	0.14
B	mg/L	0.47	0.40	0.23	0.54
Ba	mg/L	0.026	0.018	0.019	<0.013
Ca	mg/L	620.	520.	570.	610.
Cd	mg/L	0.032	0.022	<0.007	0.013
Co	mg/L	0.088	0.057	0.016	0.033
Cr	mg/L	0.14	0.079	0.034	0.070
Cu	mg/L	0.87	0.56	0.089	0.27
Fe	mg/L	0.82	0.16	0.65	0.059
Hg	mg/L	<0.0001	<0.00030	0.00025	<0.0005
K	mg/L	12.	10.	8.0	8.6
Mg	mg/L	59.	110.	98.	51.
Mn	mg/L	0.31	0.45	0.62	0.34
Mo	mg/L	0.080	0.056	0.022	0.045
Na	mg/L	430.	640.	400.	320.
Ni	mg/L	0.19	0.23	0.17	0.18
Pb	mg/L	0.54	0.37	<0.068	0.15
Se	mg/L	0.41	0.28	<0.10	0.11
V	mg/L	0.18	0.11	0.021	0.12
Zn	mg/L	3.2	4.2	5.0	2.4
F	mg/L	14.	15.	18.	17.
Cl	mg/L	100.	170.	190.	41.
HCO ₃	mg/L	580.	340.	180.	470.
TOC	mg/L	-	-	<15.	5.1
NH ₃ (N)	mg/L	1.3	0.1	<0.1	0.7
NO ₂ (N)	mg/L	4.0	1.2	0.70	3.0
NO ₃ (N)	mg/L	14.	23.	13.	9.7
SO ₄	mg/L	1870.	2450.	2180.	1830.
TDS	mg/L	3320.	3790.	3700.	3130.
TSS	mg/L	6.	150.	35.	3.
pH	units	7.0	6.6	6.5	6.9
Sp. Cond.	μmhos	3570.	5070.	4200.	4100.
Ra-224	pCi/L	13.8	28.9	4.53	3.81
Ra-226	pCi/L	1.31	4.22	0.56	0.36
Ra-228	pCi/L	17.0	<1.3	-	8.15(s)
Th-230	pCi/L	0.024	0.018	0.009	0.036
Th-232	pCi/L	0.003	0.007	0.003	0.014
U-238	mg/L	6.7	2.2	0.199	4.66

Table C.15. Continued

Chemical Species	Unit	1984			1985
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.020	0.14	<0.002	-
Al	mg/L	0.31	0.96	1.8	-
As	mg/L	0.11	0.31	<0.06	-
B	mg/L	0.28	0.36	0.77	-
Ba	mg/L	<0.013	0.016	0.17	-
Ca	mg/L	510.	590.	600.	-
Cd	mg/L	0.010	0.066	<0.002	=
Co	mg/L	0.030	0.13	0.021	-
Cr	mg/L	0.056	0.16	<0.001	-
Cu	mg/L	0.17	0.16	0.074	-
Fe	mg/L	0.44	115.	0.076	-
Hg	mg/L	<0.0003	<0.0005	<0.005	-
K	mg/L	7.0	5.7	18.	-
Mg	mg/L	130.	79.	84.	-
Mn	mg/L	0.49	1.0	0.72	-
Mo	mg/L	0.038	0.10	0.020	-
Na	mg/L	600.	200.	350.	-
Ni	mg/L	0.15	0.36	0.20	-
Pb	mg/L	0.093	0.60	<0.08	-
Se	mg/L	<0.10	0.32	<0.08	-
V	mg/L	0.041	0.16	0.057	-
Zn	mg/L	2.6	6.5	3.8	-
F	mg/L	<1.	21.	25.	-
Cl	mg/L	510.	340.	130.	-
HCO ₃	mg/L	470.	140.	190.	-
TOC	mg/L	17.	13.	35.	-
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	-
NO ₂ (N)	mg/L	4.0	-	-	-
NO ₃ (N)	mg/L	30.	21.	27.	-
SO ₄	mg/L	3290.	1820.	1660.	-
TDS	mg/L	6020.	3150.	3230.	-
TSS	mg/L	-	7.	8.	-
pH	units	8.0	7.1	7.0	-
Sp. Cond.	μmhos	7020.	3680.	3890.	-
Ra-224	pCi/L	15.2	0.	0.40	-
Ra-226	pCi/L	3.25	0.	0.09	-
Ra-228	pCi/L	11.3	2.21	0.65	-
Th-230	pCi/L	0.048	0.134	0.20	-
Th-232	pCi/L	0.006	0.008	0.006	-
U-238	mg/L	0.89	0.72	0.48	-

Source: Munson and Lambert (1981-1985).

Table C.16. Concentrations of Chemical and Radiological Parameters at Different Times in the F Wells on the West Chicago Site, Well F-3

Chemical Species	Unit	1982			1983
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.002	0.006	<0.002	0.071
Al	mg/L	1.6	0.10	1.6	1.5
As	mg/L	0.046	0.006	0.001	0.17
B	mg/L	0.36	0.40	0.21	0.30
Ba	mg/L	0.15	0.12	<0.001	<0.02
Ca	mg/L	400.	470.	450.	550.
Cd	mg/L	<0.002	0.003	0.002	0.021
Co	mg/L	0.012	0.012	0.014	0.067
Cr	mg/L	0.012	0.02	0.002	0.061
Cu	mg/L	0.17	0.1	0.17	0.32
Fe	mg/L	6.9	1.8	4.7	5.9
Hg	mg/L	<0.001	<0.001	<0.00008	0.00011
K	mg/L	3.4	4.2	3.4	4.5
Mg	mg/L	90.	71.	97.	95.
Mn	mg/L	0.68	0.27	0.68	0.82
Mo	mg/L	<0.002	<0.002	0.014	0.038
Na	mg/L	170.	95.	160.	150.
Ni	mg/L	0.12	1.089	0.14	0.27
Pb	mg/L	0.021	<0.004	<0.001	0.29
Se	mg/L	0.009	0.043	0.013	0.20
V	mg/L	0.022	0.046	0.023	0.066
Zn	mg/L	0.26	0.15	0.40	0.71
F	mg/L	16.	16.	16.	14.
Cl	mg/L	280.	120.	250.	280.
HCO ₃	mg/L	260.	232.	260.	180.
CO ₃	mg/L	<3.	<10.	<5.	<5.
NH ₃ (N)	mg/L	17.	2.5	11.	0.1
NO ₂ (N)	mg/L	<0.1	0.1	5.	0.1
NO ₃ (N)	mg/L	6.	3.2	<1.	23.
SO ₄	mg/L	1140.	1300.	1180.	1270.
TDS	mg/L	2400.	2290.	2380.	2600.
TSS	mg/L	680.	3800.	1660.	1060.
pH	units	6.5	6.6	7.2	6.6
Sp. Cond.	µmhos	2720.	2630.	3220.	3080.
Ra-224	pCi/L	-	-	-	-
Ra-226	pCi/L	0.17	0.52	0.35	0.27
Ra-228	pCi/L	<1.6	<2.0	<1.9	<2.7
Th-230	pCi/L	0.036	0.012	0.030	0.032
Th-232	pCi/L	0.006	0.003	0.009	0.003
U-238	mg/L	0.01	0.08	0.09	0.06

Table C.16. Continued

Chemical Species	Unit	1983			1984
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.16	0.10	0.057	0.021
Al	mg/L	1.4	1.5	0.80	0.80
As	mg/L	0.31	0.14	<0.11	<0.11
B	mg/L	0.36	0.44	0.31	0.32
Ba	mg/L	0.029	0.017	<0.013	<0.013
Ca	mg/L	420.	450.	420.	420.
Cd	mg/L	0.035	0.023	<0.007	0.013
Co	mg/L	0.080	0.071	0.054	0.027
Cr	mg/L	0.12	0.059	<0.026	0.033
Cu	mg/L	0.26	0.56	0.58	0.089
Fe	mg/L	3.1	6.1	9.2	0.34
Hg	mg/L	<0.0001	<0.00030	0.00028	<0.0005
K	mg/L	3.1	6.6	5.4	2.1
Mg	mg/L	48.	86.	82.	34.
Mn	mg/L	0.21	0.48	0.72	0.13
Mo	mg/L	0.074	0.039	<0.018	0.023
Na	mg/L	73.	140.	210.	27.
Ni	mg/L	0.19	0.24	0.22	0.096
Pb	mg/L	0.54	0.32	0.12	<0.068
Se	mg/L	0.43	0.21	<0.10	<0.10
V	mg/L	0.13	0.079	0.007	0.033
Zn	mg/L	0.86	1.5	1.4	0.37
F	mg/L	16.	15.	17.	17.
Cl	mg/L	70.	170.	250.	29.
HCO ₃	mg/L	180.	110.	160.	120.
TOC	mg/L	-	-	<30.	6.8
NH ₃ (N)	mg/L	1.6	7.4	<0.1	<0.1
NO ₂ (N)	mg/L	4.0	1.2	0.70	5.0
NO ₃ (N)	mg/L	<10.	13.	11.	1.5
SO ₄	mg/L	950.	1200.	1280.	960.
TDS	mg/L	1790.	2250.	2430.	1530.
TSS	mg/L	2140.	1270.	580.	3560.
pH	units	6.7	6.4	6.6	6.6
Sp. Cond.	µmhos	2000.	3190.	3150.	2110.
Ra-224	pCi/L	4.2	10.2	1.57	12.5
Ra-226	pCi/L	1.64	1.93	1.80	7.45
Ra-228	pCi/L	<1.8	<2.5	-	1.58(s)
Th-230	pCi/L	0.017	0.013	0.009	0.009
Th-232	pCi/L	0.007	0.004	0.003	0.006
U-238	mg/L	0.080	0.071	0.068	0.065

Table C.16. Continued

Chemical Species	Unit	1984			1985
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.020	0.086	<0.002	-
Al	mg/L	0.87	1.2	1.9	-
As	mg/L	<0.11	0.17	<0.06	-
B	mg/L	0.28	0.31	0.69	-
Ba	mg/L	<0.013	0.015	0.17	-
Ca	mg/L	380.	380.	310.	-
Cd	mg/L	0.015	0.042	<0.002	-
Co	mg/L	0.038	0.084	0.033	-
Cr	mg/L	0.034	0.072	<0.001	-
Cu	mg/L	0.40	0.28	0.33	-
Fe	mg/L	6.6	3.6	8.1	-
Hg	mg/L	<0.0003	<0.0005	<0.0005	-
K	mg/L	4.4	3.9	13.	-
Mg	mg/L	72.	52.	67.	-
Mn	mg/L	0.53	0.45	0.45	-
Mo	mg/L	<0.018	0.063	0.015	-
Na	mg/L	140.	82.	130.	-
Ni	mg/L	0.19	0.18	0.17	-
Pb	mg/L	<0.068	0.36	<0.08	-
Se	mg/L	<0.10	0.18	<0.08	-
V	mg/L	0.024	0.090	0.048	-
Zn	mg/L	1.2	0.78	0.83	-
F	mg/L	29.	21.	21.	-
Cl	mg/L	290.	140.	140.	-
HCO ₃	mg/L	140.	90.	170.	-
TOC	mg/L	24.	-	31.	-
NH ₃ (N)	mg/L	<0.1	<0.1	<0.01	-
NO ₂ (N)	mg/L	6.7	-	-	-
NO ₃ (N)	mg/L	18.	<1.	3.	-
SO ₄	mg/L	760.	730.	680.	-
TDS	mg/L	1980.	1350.	1590.	-
TSS	mg/L	2180.	157.	125.	-
pH	units	6.5	6.8	6.7	-
Sp. Cond.	µmhos	2920.	1940.	2120.	-
Ra-224	pCi/L	4.03	0.06	0.	-
Ra-226	pCi/L	2.06	0.03	0.07	-
Ra-228	pCi/L	6.14	0.32	2.20	-
Th-230	pCi/L	0.047	0.027	0.094	-
Th-232	pCi/L	0.005	0.004	0.014	-
U-238	mg/L	0.080	0.039	0.034	-

Source: Munson and Lambert (1981-1985).

Table C.17. Concentrations of Chemical and Radiological Parameters at Different Times in the F Wells on the West Chicago Site, Well F-4

Chemical Species	Unit	1982			1983
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.00	<0.002	<0.002	0.036
Al	mg/L	0.21	<0.1	0.05	<0.2
As	mg/L	0.025	<0.004	0.001	<0.1
B	mg/L	0.36	0.46	0.10	0.37
Ba	mg/L	0.18	0.088	0.009	0.047
Ca	mg/L	150.	170.	180.	210.
Cd	mg/L	<0.002	<0.002	0.002	0.016
Co	mg/L	0.007	0.003	0.009	<0.04
Cr	mg/L	0.014	<0.003	<0.001	0.035
Cu	mg/L	0.007	<0.001	0.003	0.076
Fe	mg/L	2.6	0.074	0.95	0.49
Hg	mg/L	0.001	0.001	<0.00009	<0.0001
K	mg/L	4.2	3.2	3.8	3.2
Mg	mg/L	80.	64.	80.	85.
Mn	mg/L	0.19	0.33	0.34	0.17
Mo	mg/L	<0.002	<0.002	0.010	0.022
Na	mg/L	120.	86.	110.	120.
Ni	mg/L	0.11	0.073	0.11	0.15
Pb	mg/L	0.028	<0.004	<0.001	0.20
Se	mg/L	0.008	0.006	0.004	<0.1
V	mg/L	0.026	<0.003	0.018	<0.04
Zn	mg/L	0.022	0.14	0.049	0.22
F	mg/L	<1.	0.68	<1.	<1.
Cl	mg/L	230.	190.	200.	840.
HCO ₃	mg/L	430.	406.	440.	375.
CO ₃	mg/L	<3.	<10.	<5.	<5.
NH ₃ (N)	mg/L	0.4	0.6	<1.	<0.1
NO ₂ (N)	mg/L	<0.1	<0.1	<0.1	<0.1
NO ₃ (N)	mg/L	1.	<1.	<1.	14.
SO ₄	mg/L	370.	280.	350.	350.
TDS	mg/L	1120.	1020.	1060.	1270.
TSS	mg/L	280.	<2.	5.	83.
pH	units	7.2	7.0	7.7	7.2
Sp. Cond.	µmhos	1600.	1540.	1730.	1840.
Ra-224	pCi/L	-	-	-	-
Ra-226	pCi/L	1.37	0.15	0.21	0.27
Ra-228	pCi/L	<1.6	<1.6	<1.3	4.9
Th-230	pCi/L	0.032	0.012	0.087	0.018
Th-232	pCi/L	0.003	0.004	0.012	0.004
U-238	mg/L	0.003	0.005	0.006	0.003

Table C.17. Continued

Chemical Species	Unit	1983			1984
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.11	<0.020	<0.020	<0.020
Al	mg/L	0.45	0.10	0.042	<0.008
As	mg/L	0.22	<0.11	<0.11	<0.11
B	mg/L	0.44	0.62	0.56	0.33
Ba	mg/L	0.041	0.042	0.045	0.042
Ca	mg/L	160.	150.	160.	190.
Cd	mg/L	0.020	<0.007	<0.007	0.008
Co	mg/L	0.059	<0.011	<0.011	0.021
Cr	mg/L	0.087	<0.026	<0.026	<0.026
Cu	mg/L	0.083	0.033	<0.017	<0.017
Fe	mg/L	0.38	0.065	0.062	0.054
Hg	mg/L	<0.0001	<0.00030	0.00022	<0.0005
K	mg/L	2.2	2.9	2.9	2.2
Mg	mg/L	52.	49.	57.	56.
Mn	mg/L	0.13	0.048	0.052	0.15
Mo	mg/L	0.047	<0.018	<0.018	<0.018
Na	mg/L	66.	63.	74.	72.
Ni	mg/L	0.16	0.051	0.050	0.12
Pb	mg/L	0.36	<0.068	<0.068	<0.068
Se	mg/L	0.28	<0.10	<0.10	<0.10
V	mg/L	0.089	<0.019	0.011	<0.005
Zn	mg/L	0.090	0.30	0.035	0.17
F	mg/L	<1.	<1.	<1.	<1.
Cl	mg/L	110.	110.	160.	300.
HCO ₃	mg/L	400.	330.	380.	310.
TOC	mg/L	-	-	4.	11.
NH ₃ (N)	mg/L	<0.1	0.2	<0.1	<0.1
NO ₂ (N)	mg/L	0.14	0.28	0.04	0.15
NO ₃ (N)	mg/L	5.	<1.	<1.	<1.
SO ₄	mg/L	190.	240.	260.	260.
TDS	mg/L	840.	790.	910.	1090.
TSS	mg/L	<2.	17.	32.0	8.
pH	units	7.1	6.9	7.0	7.1
Sp. Cond.	µmhos	1210.	1180.	1420.	2180.
Ra-224	pCi/L	0.13	1.36	0.05	0.15
Ra-226	pCi/L	0.08	0.64	0.21	0.18
Ra-228	pCi/L	<1.9	<1.9	-	0.19(s)
Th-230	pCi/L	0.012	0.022	0.009	0.009
Th-232	pCi/L	0.004	0.009	0.003	0.009
U-238	mg/L	0.010	0.008	0.010	0.006

Table C.17. Continued

Chemical Species	Unit	1984			1985
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.020	0.035	<0.002	<0.004
Al	mg/L	0.010	<0.11	0.70	0.85
As	mg/L	<0.11	<0.11	<0.06	<0.12
B	mg/L	0.40	0.49	0.84	0.32
Ba	mg/L	0.046	0.052	0.21	0.065
Ca	mg/L	170.	210.	170.	210.
Cd	mg/L	<0.007	0.019	<0.002	<0.004
Co	mg/L	<0.011	0.037	<0.006	<0.012
Cr	mg/L	<0.026	0.039	<0.001	<0.010
Cu	mg/L	<0.017	0.034	0.010	<0.002
Fe	mg/L	0.17	0.43	0.25	0.25
Hg	mg/L	<0.0003	<0.0005	<0.0005	<0.0005
K	mg/L	2.9	3.4	11.	<0.10
Mg	mg/L	59.	75.	64.	78.
Mn	mg/L	0.065	0.18	0.074	0.11
Mo	mg/L	<0.018	0.030	0.011	<0.004
Na	mg/L	70.	82.	99.	92.
Ni	mg/L	0.071	0.13	0.069	0.045
Pb	mg/L	<0.068	0.17	<0.08	<0.16
Se	mg/L	<0.10	<0.10	<0.08	<0.16
V	mg/L	0.007	0.038	<0.003	<0.006
Zn	mg/L	0.21	0.081	0.073	0.032
F	mg/L	<1.	<1.	<1.	<0.2
Cl	mg/L	230.	220.	140.	340.
HCO ₃	mg/L	360.	420.	420.	400.
TOC	mg/L	8.	11.	7.4	10.
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	2.5
NO ₂ (N)	mg/L	0.1	-	-	-
NO ₃ (N)	mg/L	3.	<1.	1.	1.
SO ₄	mg/L	230.	300.	220.	140.
TDS	mg/L	910.	1060.	980.	1090.
TSS	mg/L	5.	<2.	<2.	2.
pH	units	7.0	7.0	7.1	7.0
Sp. Cond.	umhos	1640.	1680.	1530.	2150.
Ra-224	pCi/L	0.04	0.01	11.	-
Ra-226	pCi/L	0.05	0.09	-	-
Ra-228	pCi/L	0.46	0.16	0.10	0.21
Th-230	pCi/L	0.073	0.079	0.094	0.027
Th-232	pCi/L	0.007	0.003	0.013	0.009
U-238	mg/L	0.201	0.008	0.007	0.006

Source: Munson and Lambert (1981-1985).

Table C.18. Concentrations of Chemical and Radiological Parameters at Different Times in the F Wells on the West Chicago Site, Well F-5

Chemical Species	Unit	1982			1983
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.009	<0.002	<0.002	0.071
Al	mg/L	0.53	0.56	0.34	0.46
As	mg/L	0.044	0.008	0.004	0.15
B	mg/L	0.33	0.32	0.15	0.28
Ba	mg/L	0.16	0.10	<0.001	<0.02
Ca	mg/L	570.	530.	500.	480.
Cd	mg/L	0.003	<0.002	<0.002	0.020
Co	mg/L	0.034	0.009	0.030	0.085
Cr	mg/L	0.018	0.011	<0.001	0.058
Cu	mg/L	0.18	0.18	0.17	0.15
Fe	mg/L	13.	1.3	5.2	7.5
Hg	mg/L	<0.001	0.001	<0.00008	<0.0001
K	mg/L	5.1	5.2	6.0	6.1
Mg	mg/L	81.	76.	86.	100.
Mn	mg/L	0.95	0.47	0.59	0.83
Mo	mg/L	0.006	<0.002	0.017	0.05
Na	mg/L	180.	140.	160.	160.
Ni	mg/L	0.14	0.12	0.22	0.32
Pb	mg/L	0.034	<0.004	<0.001	0.28
Se	mg/L	0.03	0.035	<0.001	0.20
V	mg/L	0.056	0.019	0.035	0.073
Zn	mg/L	0.14	0.15	0.15	0.21
F	mg/L	14.	19.	19.	14.
Cl	mg/L	85.	65.	110.	105.
HCO ₃	mg/L	280.	311.	330.	295.
CO ₃	mg/L	<3.	<10.	<5.	<5.
NH ₃ (N)	mg/L	0.9	0.5	<1.	<0.1
NO ₂ (N)	mg/L	<0.1	0.10	34.	<0.1
NO ₃ (N)	mg/L	1.	1.3	<1.	10.
SO ₄	mg/L	1670.	1470.	1490.	1280.
TDS	mg/L	2650.	2580.	2600.	2200.
TSS	mg/L	450.	83.	22.	42.
pH	units	6.4	6.5	7.2	6.7
Sp. Cond.	umhos	2630.	2840.	2930.	2590.
Ra-224	pCi/L	-	-	-	-
Ra-226	pCi/L	1.03	0.10	0.03	0.10
Ra-228	pCi/L	<1.9	<1.5	<1.5	<3.7
Th-230	pCi/L	0.023	0.030	0.085	0.028
Th-232	pCi/L	0.003	0.012	0.008	0.003
U-238	mg/L	0.18	0.49	0.28	0.17

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Table C.18. Continued

Chemical Species	Unit	1983			1984
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.14	0.089	0.029	<0.020
Al	mg/L	0.66	0.59	0.17	0.16
As	mg/L	0.32	0.16	<0.11	0.14
B	mg/L	0.30	0.39	0.35	0.31
Ba	mg/L	<0.02	<0.013	0.015	<0.013
Ca	mg/L	340.	460.	450.	400.
Cd	mg/L	0.023	0.015	<0.007	<0.007
Co	mg/L	0.12	0.064	0.039	0.053
Cr	mg/L	0.11	0.047	0.030	0.037
Cu	mg/L	0.19	0.20	0.12	0.070
Fe	mg/L	5.3	0.23	1.3	1.8
Hg	mg/L	<0.0001	<0.00030	0.00034	<0.0005
K	mg/L	6.0	7.0	6.7	4.8
Mg	mg/L	85.	82.	100.	65.
Mn	mg/L	0.84	0.66	0.97	0.90
Mo	mg/L	0.072	0.041	0.028	0.035
Na	mg/L	120.	100.	160.	120.
Ni	mg/L	0.38	0.23	0.32	0.32
Pb	mg/L	0.46	0.28	<0.068	<0.068
Se	mg/L	0.36	0.20	<0.10	<0.10
V	mg/L	0.12	0.077	0.037	0.022
Zn	mg/L	0.19	0.15	0.16	0.30
F	mg/L	11.	14.	13.	14.
Cl	mg/L	111.	97.	120.	140.
HCO ₃	mg/L	380.	290.	360.	370.
TOC	mg/L	-	-	7.	8.2
NH ₃ (N)	mg/L	1.9	0.3	<0.1	1.6
NO ₂ (N)	mg/L	0.14	0.40	0.70	0.1
NO ₃ (N)	mg/L	<1.	<1.	<1.	<1.
SO ₄	mg/L	910.	1140.	1500.	1020.
TDS	mg/L	1890.	2160.	2690.	2010.
TSS	mg/L	47.	175.	74.0	31.
pH	units	6.6	6.6	7.8	6.6
Sp. Cond.	µmhos	2210.	2950.	3150.	3070.
Ra-224	pCi/L	0.16	0.85	0.32	0.24
Ra-226	pCi/L	0.14	0.13	0.26	-
Ra-228	pCi/L	<1.6	<1.3	-	0.25(s)
Th-230	pCi/L	0.016	0.018	0.012	0.099
Th-232	pCi/L	0.006	0.007	0.006	0.025
U-238	mg/L	0.16	0.43	0.22	0.22

Table C.18. Continued

Chemical Species	Unit	1984			1985
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.020	0.16	<0.008	0.006
Al	mg/L	0.15	0.79	1.2	1.3
As	mg/L	<0.11	0.32	<0.06	<0.12
B	mg/L	0.27	0.44	0.85	0.21
Ba	mg/L	<0.013	0.012	0.17	0.019
Ca	mg/L	370.	500.	450.	390.
Cd	mg/L	<0.007	0.064	<0.002	<0.004
Co	mg/L	0.041	0.15	0.038	<0.012
Cr	mg/L	0.034	0.14	<0.001	<0.010
Cu	mg/L	0.085	0.16	0.075	0.071
Fe	mg/L	4.2	9.0	4.8	4.9
Hg	mg/L	<0.0003	<0.0005	<0.0005	<0.0005
K	mg/L	5.2	5.1	11.	27.
Mg	mg/L	79.	90.	110.	84.
Mn	mg/L	0.70	1.1	0.85	0.55
Mo	mg/L	0.026	0.11	0.022	0.011
Na	mg/L	120.	88.	240.	160.
Ni	mg/L	0.20	0.45	0.34	0.16
Pb	mg/L	<0.068	0.62	<0.08	<0.16
Se	mg/L	<0.10	0.37	<0.08	<0.16
V	mg/L	0.022	0.15	<0.003	0.015
Zn	mg/L	0.28	0.25	0.17	0.085
F	mg/L	14.	20.	15.	17.
Cl	mg/L	130.	150.	120.	130.
HCO ₃	mg/L	340.	330.	400.	370.
TOC	mg/L	12.	23.	12.	10.
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	0.7
NO ₂ (N)	mg/L	0.04	-	-	-
NO ₃ (N)	mg/L	4.	<1.	<1.	<8.
SO ₄	mg/L	900.	1260.	1360.	860.
TDS	mg/L	1860.	2490.	2620.	2030.
TSS	mg/L	130.	21.	15.	5.
pH	units	6.7	6.5	6.6	6.5
Sp. Cond.	µmhos	2810.	2780.	2950.	2900.
Ra-224	pCi/L	0.	0.	0.	0.
Ra-226	pCi/L	0.04	0.	0.003	0.011
Ra-228	pCi/L	0.28	0.05	0.44	0.09
Th-230	pCi/L	0.037	0.028	0.074	0.038
Th-232	pCi/L	0.006	0.008	0.016	0.009
U-238	mg/L	0.201	0.23	0.21	0.362

Source: Munson and Lambert (1981-1985).

Table C.19. Concentrations of Chemical and Radiological Parameters at Different Times in the F Wells on the West Chicago Site, Well F-6

Chemical Species	Unit	1982			1983
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.012	<0.002	<0.002	0.10
Al	mg/L	0.3	0.7	0.36	0.66
As	mg/L	0.013	0.010	0.002	0.17
B	mg/L	0.30	0.26	0.31	0.32
Ba	mg/L	0.2	0.11	0.15	<0.02
Ca	mg/L	490.	580.	570.	700.
Cd	mg/L	<0.002	0.004	<0.002	0.027
Co	mg/L	0.02	0.014	<0.006	0.065
Cr	mg/L	0.018	0.026	<0.001	0.071
Cu	mg/L	0.13	0.18	0.16	0.20
Fe	mg/L	3.	1.3	3.8	4.0
Hg	mg/L	<0.001	<0.001	<0.00008	<0.0001
K	mg/L	3.6	3.0	3.2	4.0
Mg	mg/L	72.	65.	70.	72.
Mn	mg/L	0.47	0.27	0.38	0.45
Mo	mg/L	0.007	0.014	0.011	0.063
Na	mg/L	130.	84.	99.	83.
Ni	mg/L	0.13	0.08	0.070	0.16
Pb	mg/L	0.022	<0.004	<0.001	0.37
Se	mg/L	0.018	0.025	0.012	0.24
V	mg/L	0.051	0.094	<0.003	0.12
Zn	mg/L	0.25	0.25	0.35	0.45
F	mg/L	13.	19.	15.	18.
Cl	mg/L	93.	68.	82.	86.
HCO ₃	mg/L	260.	201.	200.	360.
CO ₃	mg/L	<3.	<10.	<5.	<5.
NH ₃ (N)	mg/L	3.2	0.4	<1.	0.1
NO ₂ (N)	mg/L	<0.1	<0.1	1.0	0.1
NO ₃ (N)	mg/L	2.	3.	<1.	7.
SO ₄	mg/L	1260.	1570.	1390.	1610.
TDS	mg/L	2330.	2620.	2540.	2580.
TSS	mg/L	980.	230.	200.	37.
pH	units	6.5	6.4	7.0	6.4
Sp. Cond.	μmhos	2380.	2280.	2870.	2810.
Ra-224	pCi/L	-	-	-	-
Ra-226	pCi/L	0.06	1.06	0.14	0.24
Ra-228	pCi/L	<1.4	<1.3	<0.5	<2.8
Th-230	pCi/L	0.044	0.019	0.029	0.016
Th-232	pCi/L	0.007	0.007	0.004	0.005
U-238	mg/L	0.03	0.04	0.05	0.04

Table C.19. Continued

Chemical Species	Unit	1983			1984
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	0.15	0.11	<0.020	0.027
Al	mg/L	1.1	0.78	0.39	0.49
As	mg/L	0.34	0.18	<0.11	<0.11
B	mg/L	0.39	0.45	0.31	0.39
Ba	mg/L	0.025	<0.013	0.022	<0.013
Ca	mg/L	590.	570.	600.	660.
Cd	mg/L	0.025	0.018	<0.007	0.010
Co	mg/L	0.081	0.054	<0.011	0.030
Cr	mg/L	0.13	0.052	0.043	0.042
Cu	mg/L	0.21	0.21	0.090	0.20
Fe	mg/L	1.1	0.12	3.0	1.9
Hg	mg/L	<0.0001	<0.00030	0.00025	<0.0005
K	mg/L	3.1	5.6	3.2	2.7
Mg	mg/L	60.	66.	64.	63.
Mn	mg/L	0.19	0.27	0.36	0.35
Mo	mg/L	0.090	0.047	0.036	0.049
Na	mg/L	54.	67.	76.	77.
Ni	mg/L	0.17	0.17	<0.038	0.11
Pb	mg/L	0.50	0.35	<0.068	<0.068
Se	mg/L	0.44	0.28	0.14	0.11
V	mg/L	0.19	0.13	0.005	0.092
Zn	mg/L	0.27	0.24	0.34	0.45
F	mg/L	20.	18.	17.	21.
Cl	mg/L	40.	55.	88.	99.
HCO ₃	mg/L	200.	190.	200.	200.
TOC	mg/L	-	-	8.	7.
NH ₃ (N)	mg/L	0.2	0.1	<0.1	0.4
NO ₂ (N)	mg/L	0.28	0.14	0.04	0.1
NO ₃ (N)	mg/L	6.	<1.	<1.	2.3
SO ₄	mg/L	1325.	1520.	1490.	1610.
TDS	mg/L	2300.	2410.	2610.	2490.
TSS	mg/L	160.	47.	38.0	20.
pH	units	6.2	6.2	6.2	6.2
Sp. Cond.	µmhos	2310.	2950.	3040.	3200.
Ra-224	pCi/L	1.92	0.34	1.47	0.52
Ra-226	pCi/L	0.33	0.41	0.81	0.13
Ra-228	pCi/L	<1.5	<2.3	-	0.24(s)
Th-230	pCi/L	0.015	0.013	0.003	0.017
Th-232	pCi/L	0.003	0.004	0.003	0.004
U-238	mg/L	0.075	0.074	0.090	0.095

Table C.19. Continued

Chemical Species	Unit	1984			1985
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
Ag	mg/L	<0.020	0.18	<0.002	0.009
Al	mg/L	0.40	0.76	1.2	1.4
As	mg/L	<0.11	0.19	<0.06	<0.12
B	mg/L	0.33	0.42	0.97	0.52
Ba	mg/L	<0.013	0.016	0.17	0.032
Ca	mg/L	590.	590.	620.	550.
Cd	mg/L	0.007	0.096	<0.002	<0.004
Co	mg/L	0.017	0.14	0.025	<0.012
Cr	mg/L	<0.026	0.20	0.019	0.017
Cu	mg/L	0.13	0.20	0.14	0.013
Fe	mg/L	2.2	4.9	4.2	0.82
Hg	mg/L	<0.0003	<0.0005	0.0014	<0.005
K	mg/L	3.1	3.5	9.	0.93
Mg	mg/L	63.	60.	73.	61.
Mn	mg/L	0.29	0.57	0.35	0.17
Mo	mg/L	0.026	0.089	0.070	0.020
Na	mg/L	71.	42.	110.	82.
Ni	mg/L	0.080	0.29	0.089	0.048
Pb	mg/L	<0.068	0.72	<0.08	<0.16
Se	mg/L	<0.10	0.26	<0.08	<0.16
V	mg/L	0.062	0.23	0.12	0.096
Zn	mg/L	0.32	0.43	0.26	0.15
F	mg/L	36.	22.	21.	22.
Cl	mg/L	160.	96.	86.	72.
HCO ₃	mg/L	200.	210.	210.	230.
TOC	mg/L	9.1	15.	5.4	8.
NH ₃ (N)	mg/L	<0.1	<0.1	<0.1	1.0
NO ₂ (N)	mg/L	0.1	-	-	-
NO ₃ (N)	mg/L	9.	5.	<1.	4.
SO ₄	mg/L	1390.	1440.	1560.	1080.
TDS	mg/L	2440.	2510.	2630.	2320.
TSS	mg/L	2.	15.	18.	110.
pH	units	6.2	6.3	6.4	6.3
Sp. Cond.	µmhos	2930.	2780.	2890.	2960.
Ra-224	pCi/L	0.44	-	-	0.50
Ra-226	pCi/L	0.11	-	-	-
Ra-228	pCi/L	0.77	0.13	0.35	0.80
Th-230	pCi/L	0.050	0.044	0.072	0.022
Th-232	pCi/L	0.005	0.006	0.013	0.007
U-238	mg/L	0.115	0.10	0.076	0.101

Source: Munson and Lambert (1981-1985).

Table C.20. Concentrations of Chemical and Radiological Parameters at Different Times in the F Wells on the West Chicago Site, Well F-7

Chemical Species	Unit	1984
		4th Qtr.
Ag	mg/L	<0.002
Al	mg/L	3.9
As	mg/L	<0.06
B	mg/L	2.8
Ba	mg/L	0.17
Ca	mg/L	530.
Cd	mg/L	<0.002
Co	mg/L	0.043
Cr	mg/L	0.039
Cu	mg/L	<0.001
Fe	mg/L	280.
Hg	mg/L	<0.0005
K	mg/L	30.
Mg	mg/L	520.
Mn	mg/L	6.
Mo	mg/L	0.051
Na	mg/L	1200.
Ni	mg/L	0.58
Pb	mg/L	<0.08
Se	mg/L	<0.08
V	mg/L	<0.003
Zn	mg/L	0.88
F	mg/L	<1.
Cl	mg/L	810.
HCO ₃	mg/L	<5.
TOC	mg/L	94.
NH ₃ (N)	mg/L	31.
NO ₂ (N)	mg/L	-
NO ₃ (N)	mg/L	<1.
SO ₄	mg/L	4530.
TDS	mg/L	8630.
TSS	mg/L	670.
pH	units	5.6
Sp. Cond.	μmhos	9440.
Ra-224	pCi/L	13.6
Ra-226	pCi/L	1.52
Ra-228	pCi/L	7.34
Th-230	pCi/L	0.033
Th-232	pCi/L	0.005
U-238	mg/L	0.003

Source: Munson and Lambert
(1981-1985).

REFERENCE (Appendix C)

Munson, S., and K. Lambert. 1981-1985. Data sheets of monitoring wells, West Chicago, 1981-1985. Kerr-McGee Corporation, Technology Division.

APPENDIX D. ECOLOGICAL DATA

Table D.1. Common Birds Likely to Occur from Counties Where Potential Alternative Disposal Sites are Located

Species	Seasonal Occurrence	Habitat
American goldfinch	All year	Woody fields, bushes, roadsides, seed-bearing trees
American kestrel	Migrant	Open and semi-open country
American woodcock	Summer	Moist woodlands, swamps, thickets
Baltimore oriole	Summer	Tall elms and other shade trees
Barn swallow	Summer	Near farms
Belted kingfisher	All year	Along streams and ponds
Black-and-white warbler	Summer	Deciduous woods
Black-capped chickadee	All year	Nests in tree cavities
Blue jay	All year	Oak and pine woods
Blue-winged teal	Migrant	Ponds, marshes
Bobwhite	All year	Brush, abandoned fields, open pinelands
Brown creeper	Winter	Woodlands
Brown-headed cowbird	Summer	Farmlands
Brown thrasher	Summer	Brushy habitats, wood margins, residential areas
Canada goose	Migrant	Grazes in open fields
Cardinal	All year	Hedgerows, wood margins, suburbs
Carolina wren	All year	Thick underbrush
Chimney swift	Summer	Roosts in tall chimneys
Common crow	All year	Open country
Common gallinule	Summer	Marshes, lake margins
Common grackle	Summer to all year	Farmlands, suburbs
Common nighthawk	Summer	Cities
Common snipe	Migrant and summer	Marshes, bogs, river banks
Downy woodpecker	All year	Suburbs, orchards, shade trees, woods
Eastern bluebird	All year	Roadsides, farmyards, abandoned orchards
Eastern kingbird	Summer	Open and semi-open country
Eastern meadowlark	All year	Fields, fencerows
Eastern phoebe	Summer	Farm buildings, bridges
Eastern wood pewee	Summer	Deciduous and mixed woods
Field sparrow	Summer to all year	Abandoned fields with tall grass or scattered saplings
Grasshopper sparrow	Summer	Hay fields, weedy fallow fields
Great crested flycatcher	Summer	Deciduous and mixed woods
Green heron	Summer	Small ponds, wooded streams
Green-winged teal	Migrant	Small ponds, lakes
Hairy woodpecker	All year	Deciduous and mixed woods
Horned lark	All year	Fields, shores, open places
House sparrow	All year	Farms, cities, suburbs
Indigo bunting	Summer	Hedgerows, wood margins

Table D.1. Continued

Species	Seasonal Occurrence	Habitat
Killdeer	All year	Fields, pastures
King rail	Summer	Marshes
Least flycatcher	Migrant or summer	Scrub growth, wood margins, unsprayed orchards
Mallard	Summer to all year	Ponds, marshes
Marsh hawk	All year	Grasslands, marshes
Mockingbird	All year	Brushy habitats, wood margins, residential areas
Mourning dove	All year	Suburbs, farmlands
Ovenbird	Summer	Deciduous woods
Pheasant	All year	Open woods; farmlands in brush, hedgerows, cornfields
Prairie warbler	Summer	Deciduous saplings, young pine stands, wood margins
Purple finch	Winter	Open woodlands, suburbs
Red-eyed vireo	Summer	Deciduous forest
Red-headed woodpecker	All year	Open deciduous woods
Red-shouldered hawk	Summer to all year	Moist woodlands often close to cultivated fields
Red-tailed hawk	Summer to all year	Nests in woodlands, feeds in open country
Red-winged blackbird	Summer	Marshes, fields
Robin	Summer to all year	Open areas
Rock dove (pigeon)	All year	Farmyards, cities, suburbs
Ruby-throated hummingbird	Summer	Woods, gardens
Rufous-sided towhee	All year	Brush, hedgerows, wood margins, heavy undergrowth
Scarlet tanager	Summer	Deciduous and pine-oak woods
Screech owl	All year	Towns, orchards, small woodlots
Semipalmated sandpiper	Migrant	Along water bodies
Sharp-shinned hawk	All year	Open woods, wood margins
Short-eared owl	Winter to all year	Plains, sloughs, marshes
Song sparrow	All year	Bushes, hedgerows, wood margins
Spotted sandpiper	Summer	Along water bodies
Starling	All year	City parks, suburbs, farmlands
Tree sparrow	Winter	Willow thickets, weedy fields, hedgerows
Virginia rail	Summer	Marshes
Whip-poor-will	Summer	Woods near fields
White-breasted nuthatch	All year	Deciduous woods
White-eyed vireo	Summer	Moist deciduous thickets, wood margins, hedgerows
Wood thrush	Summer	Deciduous forests and shrubs
Yellow warbler	Summer	Willow thickets, orchards, suburbs
Yellow-bellied sapsucker	Summer and/or winter	Woods, orchards
Yellow-billed cuckoo	Summer	Brush, woods
Yellow-shafted flicker	All year	Open country near large trees
Yellowthroat	Summer	Moist grassy or shrubby areas

Source: Robbins et al. (1966).

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Table D.2. Common Reptiles and Amphibians Reported from Counties Where Potential Alternative Disposal Sites are Located

Species	Counties	Habitat
Small-mouthed salamander	Douglas, Fulton	Woodlands and prairies; also pasture areas and cultivated black soils
Eastern tiger salamander	All	Abundant only in areas with numerous ponds; persists in disturbed areas, e.g., cities and cultivated regions
Central newt	DuPage	Ponds and marshes
Mudpuppy	All	Lakes, lagoons, large creeks, and rivers
American toad	All	Woods and fields
Fowler's toad	Douglas, Fulton, Peoria	Sand prairies and margins of lakes and streams
Cricket frog	All	Almost any wet place
Chorus frog	All	Temporary pools and ditches; essentially a prairie species; abundant in cultivated areas of state
Spring peeper	All	Mesic forests; not in small woodlots surrounded by prairie or cultivated fields
Gray treefrog	All	Forests; may be absent from forest areas surrounded by prairie
Bullfrog	All	Permanent water bodies
Green frog	Douglas, Fulton, Peoria	Most water bodies (northern Illinois) or clear streams near rock outcrops (central Illinois)
Leopard frog	All	Streams, ponds, and lakes. Often in fields some distance from water
Snapping turtle	All	Most water bodies; will migrate overland between water bodies
Stinkpot	All	Ponds and shallow lakes; also rivers and small streams
Ornate box turtle	Fulton, Peoria	Prairies and fields
Painted turtle	All	Most water bodies; but may be found some distance from water
Red-eared turtle	Douglas, Fulton, Livingston, Peoria	Most water bodies, except fast-flowing streams
Smooth softshell turtle	Fulton, Peoria	Restricted to rivers with relatively clean, sandy bottoms and numerous sandbars
Spiny softshell turtle	All	Lakes, sloughs, mud-bottomed streams, and sand-bottomed rivers
Eastern hognose snake	All	Lakes, sloughs, mud-bottomed streams, and sand-bottomed rivers
Smooth green snake	DuPage, Fulton, Livingston, Peoria	Prairies, wet meadows, and vacant suburban lots
Blue racer	All	Widespread forest edge; rare in heavily farmed muck prairies
Black rat snake	Douglas, Fulton	Wooded bluffs; rare in prairie areas

Table D.2. Continued

Species	Counties	Habitat
Western fox snake	DuPage, Fulton, Livingston, Peoria	Cultivated muck prairies, fencerows, and pastures; rare in forested areas.
Bull snake	Fulton, Peoria	Sand prairies; sporadic in small wooded areas
Prairie kingsnake	Douglas, Fulton, Peoria	Old fields; uncommon in cultivated muck prairies
Milk snake	All	Prefers, but not confined to, forests
Eastern plains garter snake	DuPage, Fulton, Livingston, Peoria	Vacant lots, trashy areas, pastures, and muck prairie areas
Eastern garter snake	All	Various habitats; prefers forest edge
De Kay's snake	All	Forest and prairie habitats; most often in partially wooded pastures and parklike groves
Northern red-bellied snake	All	Forests, pastures, and wet meadows
Graham's water snake	All	Sluggish waters of prairie areas
Kirtland's water snake	Douglas	Vacant lots, wooded ravines, and ditches in cultivated fields
Queen snake	DuPage	Fast streams in forested areas
Water snake	All	Mostly streams; also lakes and ponds
Eastern massasauga	All	Prairie marshes, old fields, bogs, and wooded areas

Source: Smith (1961); Conant (1975).

Table D.3. Mammal Species Common to the Counties Where Potential Alternative Disposal Sites are Located

Species	Habitat
Opossum	Farming areas preferred, also woodlands and along streams
Short-tailed shrew	Forests, grasslands, marshes, brushy areas
Eastern mole	Moist sandy loam, lawns, golf courses, fields, meadows, gardens
Little brown bat	Caves, mine tunnels, hollow trees, buildings
Keen myotis	Mine tunnels, caves, hollow trees, storm sewers, forested areas
Eastern pipistrel	Caves, mine tunnels, rock crevices, buildings, wooded areas
Red bat	Wooded areas, occasionally enters caves
Big brown bat	Caves, tunnels, crevices, hollow trees, buildings, wooded areas
Raccoon	Along streams and lake borders near wooded areas or rock cliffs
Long-tailed weasel	All land habitats near water
Mink	Along streams and lakes
Striped skunk	Semi-open country, mixed woods, brushland, prairies (usually stays near water)
Red fox	Mixture of forest and open country
Woodchuck	Open woods, brushy and rocky ravines
Thirteen-lined ground squirrel	Shortgrass prairies, golf courses, pastures, roadsides
Franklin ground squirrel	Tall grass prairies, open woods, borders of fields, marsh borders
Eastern chipmunk	Deciduous forests; brushy areas; rocky, woody ravines
Eastern gray squirrel	Hardwood forests, river bottoms
Eastern fox squirrel	Open hardwoods, woodlots
White-footed mouse	Woody or brushy areas preferred; sometimes open areas
Deer mouse	Most dry-land habitats
Meadow vole	Low moist areas; high grasslands; near streams, lakes, swamps; orchards with grass undergrowth; occasionally forests
Muskrat	Marshes, edges of ponds, lakes and streams
Norway rat	Buildings, rubbish piles, garbage dumps, feed lots, croplands
House mouse	Buildings, occasionally fields
Eastern cottontail	Heavy brush, forest strips with open areas nearby, edges of swamps, weed patches
White-tailed deer	Forests, swamps, open brushy areas

Sources: Hoffmeister and Mohr (1972); Burt and Grossenheider (1964).

Table D.4. Fish Species Common to the Counties Where Potential Alternative Disposal Sites are Located

Species	County	Habitat
Grass pickerel	All	Quiet pools of streams, marshes, sloughs, and swamps
Northern pike	DuPage, Livingston	Lakes, marshes, pools of creeks, large rivers
Goldfish	All	Quiet pools with submerged vegetation
Carp	All	Most aquatic habitats, but prefers soft-bottomed pools of rivers
Golden shiner	All	Clear, well-vegetated ponds and lakes and quiet pools of creeks and small rivers
Creek chub	All	Creeks, especially low-gradient streams with mud or clay substrates
Honeyhead chub	All	Clear, high gradient creeks and small rivers
Blacknose dace	Fulton, Peoria	Clear, fast, gravelly brooks or runs
Suckermouth minnow	Douglas, Fulton, Livingston, Peoria	Relatively silt-free riffles and raceways
Striped shiner	All	Clear water of fast to moderately flowing small brooks and large creeks
Bigmouth shiner	All	Shallow water creeks and small rivers; occasionally big rivers
Ribbon shiner	Douglas	Low gradient creeks over substrates of sand, clay or mud
Red shiner	Douglas, Fulton, Livingston, Peoria	Creeks with moderate flows and bottoms of sand or mixed sand-silt-gravel
Rosyface shiner	Livingston	Clear, fast large creeks and small rivers with bottoms of clean gravel
Spotfin shiner	Douglas	Large creeks and small rivers in clear raceways over gravel or mixed gravel-sand-silt
Sand shiner	Douglas, Fulton, Livingston, Peoria	Creeks to large rivers and clear natural and artificial lakes over sand or gravel
Redfin shiner	Douglas, Livingston	Clear, low gradient creeks
Silverjaw minnow	Douglas, Livingston	Shifting sand bottoms in riffles and raceways with moderate flow
Southern redbelly dace	Peoria	Spring-fed brooks and other cool streams
Bluntnose minnow	All	Prefers hard-bottomed pools in creeks and small rivers; but occurs in all habitats except swamps and heavily silted ditches and ponds
Fathead minnow	All	Sluggish creeks, ditches, and ponds with mud bottoms; also backwaters and mud-bottomed pools of larger rivers
Common stoneroller	All	Creeks with bottoms of gravel, bedrock, or mixed sand-gravel in riffles and raceways
Quillback	Douglas, Fulton, Livingston, Peoria	Creeks, rivers, and small lakes
Golden redbhorse	Douglas, Fulton, Livingston, Peoria	Raceways and firm-bottomed pools of creeks and small rivers
Northern hog sucker	Douglas, Fulton, Livingston, Peoria	Clear, fast riffles and raceways with pebbly or sand-gravel bottoms
White sucker	All	Prefers clear, sandy or gravelly creeks and small rivers; but occurs in any water body

Table D.4. Continued

Species	County	Habitat
Spotted sucker	Douglas, Fulton	Clear firm-bottomed creeks and small rivers; but ranges from turbid creeks to large rivers
Creek chubsucker	Douglas, Livingston	Low gradient creeks; most abundant in quiet pools with much debris, vegetation and overhanging roots
Black bullhead	All	Lakes, ponds, swamps, and pool habitats of all size streams
Yellow bullhead	All	Streams
Tadpole madtom	Douglas, DuPage, Livingston	Lakes, swamps, and sluggish muck-bottomed pools of creeks
Pirate perch	Douglas	Swamps, ponds, ditches, and muck-bottomed pools of low-gradient creeks and small rivers
Blackstripe topminnow	Douglas, Livingston	Quiet waters of creeks, rivers, lakes, swamps, and ponds
Smallmouth bass	All	Clear, gravelly or rocky rivers that have moderate to fast current and relatively cool summer temperatures
Largemouth bass	All	Most types of water, prefers weedy oxbows and clear floodplain lakes
Green sunfish	All	Small ponds and sluggish creeks
Orangespotted sunfish	All	Most waters except swiftly flowing streams
Bluegill	All	Clear well-vegetated lakes, swamps, ponds, and pools of variously sized streams
Longer sunfish	Douglas, Livingston	Sand and gravel-bottomed pools of creeks and small rivers
Rock bass	Livingston	Clear gravelly rivers
Blackside darter	All	Firm-bottomed pools of creeks and small rivers; sometimes ascends into headwaters
Rainbow darter	Douglas	Clear fast riffles over gravel and rock rubble in creeks and small rivers
Fantail darter	Douglas, DuPage, Peoria	Fast rocky riffles or rivulets, creeks, and small rivers
Johnny darter	All	Pools of creeks with bottoms of mixed sand, silt and gravel
Orangethroat darter	Douglas, DuPage, Fulton, Peoria	Riffles and pools of small creeks with bottoms of mixed sand and gravel

Source: Smith (1979).

Table D.5. Plant Species Common to Potential Alternative Disposal Sites in Illinois

Species	Habitat ^a
<u>GRASSES</u>	
<u>Hordeum</u> (Barley)	Roadsides; fields, meadows, pastures
<u>Agrostis</u> (Bent grass)	Roadsides; fields, meadows, pastures; woods; sandy or gravelly soil; cultivated land, lawns
<u>Poa</u> (Blue grass)	Roadsides; fields, meadows, pastures; waste grounds; woods; cultivated land, lawns; thickets
<u>Andropogon</u> (Bluestem)	Open woods; sandy or gravelly soil; prairie soil
<u>Bromus</u> (Brome)	Roadsides; fields, meadows, pastures; waste grounds; open woods; woods; slopes, hillsides
<u>Phalaris</u> (Canary grass)	Roadsides; waste grounds; marshes, wet meadows, wet ground
<u>Spartina</u> (Cord grass)	Roadsides; ditches; marshes, wet meadows, wet ground
<u>Alopecurus</u> (Foxtail)	Fields, meadows, pastures; waste grounds; ditches; banks, shorelines; shallow water
<u>Setaria</u> (Foxtail)	Roadsides; fields, meadows, pastures; waste grounds
<u>Eragrostis</u> (Love grass)	Roadsides; waste grounds; open woods; sandy or gravelly soil; cultivated land, lawns; banks, shorelines
<u>Panicum</u> (Panic Grass)	Roadsides; fields, meadows, pastures; waste grounds; swales; open woods; sandy or gravelly soil; slopes, hillsides
<u>Paspalum</u> (Paspalum)	Roadsides; sandy or gravelly soil
<u>Lolium</u> (Rye grass)	Roadsides; fields, meadows, pastures; cultivated land, lawns
<u>Sphenopholis</u> (Wedge grass)	Roadsides; fields, meadows, pastures; open woods; woods; prairie soil
<u>Agropyron</u> (Wheat grass)	Fields, meadows, pastures; waste grounds; along railroads
<u>FORBS, HERBS, ETC.</u>	
<u>Medicago</u> (Alfalfa)	Roadsides; fields
<u>Amaranthus</u> (Amaranth)	Roadsides; fields, meadows, pastures; waste grounds
<u>Anemone</u> (Anemone)	Roadsides; open woods; woods; prairie soil; slopes, hillsides; bluffs, cliffs, ledges
<u>Sagittaria</u> (Arrowhead)	Ditches; banks, shorelines; shallow water
<u>Aster</u> (Aster)	Roadsides; fields, meadows, pastures; waste grounds; ditches; open woods; woods; sandy or gravelly soil; prairie soil; marshes, wet meadows, wet ground; banks, shorelines; bluffs, cliffs, ledges
<u>Geum</u> (Avens)	Roadsides; woods; thickets
<u>Galium</u> (Bedstraw)	Roadsides; fields, meadows, pastures; waste grounds; woods; thickets
<u>Bidens</u> (Beggar-ticks)	Roadsides; fields, meadows, pastures; swales; open woods; woods; marshes, wet meadows, wet ground
<u>Scirpus</u> (Bulrush)	Ditches; marshes, wet meadows, wet ground; swamps, wet woods, bogs; banks, shorelines; shallow water
<u>Lespedeza</u> (Bush-clover)	Roadsides; fields, meadows, pastures; open woods; woods
<u>Ranunculus</u> (Buttercup)	Roadsides; fields, meadows, pastures; ditches; woods; marshes, wet meadows, wet ground; shallow water
<u>Daucus</u> (Carrot)	Roadsides; fields, meadows, pastures; waste grounds
<u>Nepeta</u> (Catnip)	Roadsides; fields, meadows, pastures; waste grounds; open woods
<u>Typha</u> (Cattail)	Ditches; marshes, wet meadows, wet ground; shallow water

Table D.5. Continued

Species	Habitat ^a
<u>Stellaria</u> (Chickweed)	Fields, meadows, pastures; waste grounds; marshes, wet meadows, wet ground
<u>Potentilla</u> (Cinquefoil)	Roadsides; waste grounds; sandy or gravelly soil; marshes, wet meadows, wet ground
<u>Trifolium</u> (Clover)	Roadsides; fields, meadows, pastures; waste grounds; open woods; woods; cultivated land, lawns
<u>Silphium</u> (Compass-plant)	Prairie soil; marshes, wet meadows, wet ground
<u>Rudbeckia</u> (Coneflower)	Roadsides; fields, meadows, pastures; open woods; woods; prairie soil; marshes, wet meadows, wet ground
<u>Taraxacum</u> (Dandelion)	Roadsides; fields, meadows, pastures; waste grounds; cultivated land, lawns
<u>Rumex</u> (Dock)	Roadsides; fields, meadows, pastures; waste grounds; marshes, wet meadows, wet ground
<u>Lemna</u> (Duckweed)	Ditches; marshes, wet meadows, wet ground; swamps, wet woods, bogs; shallow water
<u>Oenothera</u> (Evening-primrose)	Roadsides; fields, meadows, pastures; waste grounds; sandy or gravelly soil
<u>Dryopteris</u> (Fern)	Marshes, wet meadows, wet ground; swamps, wet woods, bogs; bluffs, cliffs, ledges; ravines
<u>Erigeron</u> (Fleabane)	Roadsides; fields, meadows, pastures; waste grounds; open woods
<u>Solidago</u> (Goldenrod)	Roadsides; fields, meadows, pastures; woods edge; woods; thickets; prairie soil; marshes, wet meadows, wet ground; slopes, hillsides
<u>Chenopodium</u> (Goosefoot)	Roadsides; fields, meadows, pastures; waste grounds; woods; sandy or gravelly soil; cultivated land, lawns
<u>Equisetum</u> (Horsetail)	Ditches; sandy or gravelly soil; marshes, wet meadows, wet ground; banks, shorelines; shallow water
<u>Vernonia</u> (Ironweed)	Roadsides; fields, meadows, pastures; open woods; woods; marshes, wet meadows, wet ground
<u>Impatiens</u> (Jewel-weed)	Swamps, wet woods, bogs
<u>Polygonum</u> (Knotweed)	Roadsides; fields, meadows, pastures; waste grounds; ditches; woods; sandy or gravelly soil; thickets; marshes, wet meadows, wet ground; fencerows, hedgerows
<u>Lysimachia</u> (Loosestrife)	Roadsides; fields, meadows, pastures; waste grounds; open woods; woods; thickets; marshes, wet meadows, wet ground
<u>Lythrum</u> (Loosestrife)	Roadsides; marshes, wet meadows, wet ground; swamps, wet woods, bogs
<u>Malva</u> (Mallow)	Fields, meadows, pastures; waste grounds
<u>Podophyllum</u> (Mayapple)	Woods
<u>Asclepias</u> (Milkweed)	Roadsides; fields, meadows, pastures; waste grounds; ditches; open woods; woods; swamps, wet woods, bogs; banks, shorelines
<u>Pycnanthemum</u> (Mountain mint)	Roadsides; fields, meadows, pastures; open woods; woods
<u>Cerastium</u> (Mouse-ear chickweed)	Fields, meadows, pastures; waste grounds; sandy or gravelly soil; cultivated land, lawns; marshes, wet meadows, wet ground
<u>Brassica</u> (Mustard)	Fields, meadows, pastures; waste grounds

Table D.5. Continued

Species	Habitat ^a
<u>Solanum</u> (Nightshade)	Roadsides; fields, meadows, pastures; waste grounds; open woods; cultivated land, lawns; marshes, wet meadows, wet ground
<u>Allium</u> (Onion)	Roadsides; fields, meadows, pastures; waste grounds; woods; banks, shorelines
<u>Pastinaca</u> (Parsnip)	Roadsides; fields, meadows, pastures; waste grounds
<u>Phlox</u> (Phlox)	Roadsides; open woods; woods; marshes, wet meadows, wet ground
<u>Plantago</u> (Plantain)	Roadsides; fields, meadows, pastures; waste grounds; open woods; cultivated land, lawns
<u>Potamogeton</u> (Pondweed)	Ditches; shallow water
<u>Ambrosia</u> (Ragweed)	Roadsides; fields, meadows, pastures; waste grounds
<u>Hibiscus</u> (Rose mallow)	Roadsides; fields, meadows, pastures; waste grounds; swamps, wet woods, bogs; banks, shorelines
<u>Juncus</u> (Rush)	Roadsides; fields, meadows, pastures; ditches; open woods; sandy or gravelly soil; marshes, wet meadows, wet ground; banks, shorelines
<u>Hypericum</u> (St. John's-wort)	Roadsides; fields, meadows, pastures; open woods; banks, shorelines
<u>Carex</u> (Sedge)	Roadsides; fields, meadows, pastures; ditches; woods edge; open woods; woods; thickets; prairie soil; marshes, wet meadows, wet ground; swamps, wet woods, bogs; banks, shorelines
<u>Cyperus</u> (Sedge)	Fields, meadows, pastures; ditches; sandy or gravelly soil; marshes, wet meadows, wet ground; banks, shorelines
<u>Scutellaria</u> (Skullcap)	Roadsides; woods; marshes, wet meadows, wet ground; banks, shorelines; slopes, hillsides; bluffs, cliffs, ledges
<u>Veronica</u> (Speedwell)	Roadsides; fields, meadows, pastures; waste grounds; ditches; cultivated land, lawns; banks, shorelines
<u>Eleocharis</u> (Spike rush)	Ditches; marshes, wet meadows, wet ground; swamps, wet woods, bogs; shallow water.
<u>Claytonia</u> (Spring beauty)	Roadsides; woods
<u>Chamaesyce</u> (Spurge)	Roadsides; fields, meadows, pastures; sandy or gravelly soil; cultivated land, lawns
<u>Fragaria</u> (Strawberry)	Roadsides; waste grounds; open woods; banks, shorelines
<u>Helianthus</u> (Sunflower)	Roadsides; fields, meadows, pastures; waste grounds; open woods; sandy or gravelly soil; prairie soil; marshes, wet meadows, wet ground
<u>Osmorhiza</u> (Sweet cicely)	Woods
<u>Cirsium</u> (Thistle)	Roadsides; fields, meadows, pastures; waste grounds; woods; marshes, wet meadows, wet ground
<u>Desmodium</u> (Tick clover)	Roadsides; open woods; woods; prairie soil
<u>Verbena</u> (Vervain)	Roadsides; fields, meadows, pastures; waste grounds; open woods
<u>Viola</u> (Violets)	Roadsides; fields, meadows, pastures; waste grounds; woods edge; open woods; marshes, wet meadows, wet ground
<u>Hydrophyllum</u> (Waterleaf)	Woods
<u>Elodea</u> (Waterweed)	Shallow water

Table D.5. Continued

Species	Habitat ^a
<u>Geranium</u> (Wild geranium)	Roadsides; fields, meadows, pastures; waste grounds; open woods; swamps, wet woods, bogs
<u>Oxalis</u> (Wood sorrel)	Roadsides; fields, meadows, pastures; open woods; woods
<u>Rorippa</u> (Yellow cress)	Fields, meadows, pastures; marshes, wet meadows, wet ground; banks, shorelines; shallow water
TREES AND SHRUBS	
<u>Fraxinus</u> (Ash)	Roadsides; woods
<u>Populus</u> (Aspen)	Woods edge; thickets; banks, shorelines; bluffs, cliffs, ledges
<u>Rubus</u> (Bramble)	Roadsides; fields, meadows, pastures; open woods; thickets; marshes, wet meadows, wet ground; fencerows, hedgerows
<u>Rhamnus</u> (Buckthorn)	Roadsides; woods edge; banks, shorelines; bluffs, cliffs, ledges
<u>Prunus</u> (Cherry, Plum)	Roadsides; woods edge; sandy or gravelly soil; marshes, wet meadows, wet ground; swamps, wet woods, bogs; fencerows, hedgerows
<u>Cornus</u> (Dogwood)	Roadsides; open woods; woods; marshes, wet meadows, wet ground; fencerows, hedgerows
<u>Ulmus</u> (Elm)	Woods
<u>Ribes</u> (Gooseberry)	Woods; swamps, wet woods, bogs; banks, shorelines
<u>Vitis</u> (Grape)	Woods; thickets; banks, shorelines; fencerows, hedgerows
<u>Smilax</u> (Greenbrier)	Woods; thickets
<u>Celtis</u> (Hackberry)	Woods
<u>Crataegus</u> (Hawthorn)	Fields, meadows, pastures; open woods; thickets; banks, shorelines
<u>Carya</u> (Hickory)	Woods
<u>Acer</u> (Maple)	Open woods; woods; swamps, wet woods, bogs
<u>Morus</u> (Mulberry)	Woods; fencerows, hedgerows
<u>Quercus</u> (Oak)	Open woods; woods; swamps, wet woods, bogs; banks, shorelines; slopes, hillsides; bluffs, cliffs, ledges
<u>Maclura</u> (Osage-orange)	Fencerows, hedgerows
<u>Cercis</u> (Redbud)	Woods
<u>Rosa</u> (Rose)	Fields, meadows, pastures; woods edge; thickets; fencerows, hedgerows
<u>Sassafras</u> (Sassafras)	Woods
<u>Rhus</u> (Sumac)	Roadsides; fields, meadows, pastures; waste grounds; woods edge; open woods; woods; sandy or gravelly soil; fencerows, hedgerows
<u>Platanus</u> (Sycamore)	Woods; banks, shorelines
<u>Viburnum</u> (Viburnum)	Thickets; swamps, wet woods, bogs; banks, shorelines
<u>Baptisia</u> (Wild Indigo)	Open woods; prairie soil
<u>Salix</u> (Willow)	Sandy or gravelly soil; marshes, wet meadows, wet ground; swamps, wet woods, bogs; banks, shorelines

^a Varying habitats due to generalized habitat requirements or, more often, due to a number of common species each with specific habitat requirements.

Source: Jones (1963).

Table D.6. Illinois-Listed Endangered and Threatened Plant Species
Reported from Counties Where Potential Alternative
Disposal Sites are Located

Species	Status ^a	County	Habitat
<u>Arctostaphylos uva-ursi</u>	E	Peoria	Woods and dunes
<u>Arenaria patula</u>	T	DuPage	Wooded slopes along streams
<u>Artemisia dracunculus</u>	T	Peoria	Prairie soil
<u>Asclepias lanuginosa</u>	E	DuPage	Dry ground
<u>Asclepias meadii</u>	E	Fulton, Peoria	Dry ground
<u>Aster schreberi</u>	T	Peoria	Wooded ravines
<u>Betula lutea</u>	E	DuPage	Wooded areas
<u>Calopogon tuberosus</u>	T	DuPage, Peoria	Mesic sand prairies, fens, and sphagnum-associated habitat
<u>Comassia angusta</u>	E	Peoria	Moist woods or meadows
<u>Carex communis</u>	E	Peoria	Dry woods
<u>Carex crawei</u>	E	DuPage	Sandy soil
<u>Carex intumescens</u>	E	Livingston, Peoria	Swampy woods
<u>Carex laxiculmis</u>	E	Fulton, Peoria	Rich woods
<u>Carex pallescens</u>	E	Fulton	Moist ground
<u>Carex rostrata</u>	E	DuPage	Ditches and shores
<u>Carex viridula</u>	E	DuPage	Lake shores and river banks
<u>Castilleja sessiliflora</u>	E	DuPage	Gravelly or sandy soil
<u>Chamaesyce polygonifolia</u>	E	Fulton	Sandy soil
<u>Corallorhiza maculata</u>	T	DuPage	Woods
<u>Cypripedium candidum</u>	E	DuPage, Peoria	Bogs, swamps, or wet prairie ground
<u>Cypripedium reginae</u>	E	Peoria	Wet woods or springy places
<u>Dodecatheon amethystinum</u>	E	Fulton	Bluffs
<u>Epilobium strictum</u>	T	Peoria	Wet ground
<u>Filipendula rubra</u>	T	DuPage, LaSalle, Peoria	Moist ground
<u>Geranium bicknellii</u>	E	DuPage	Fields and open woods
<u>Glyceria canadensis</u>	E	Peoria	Wet ground
<u>Habenaria flava</u> var. <u>herbiola</u>	T	Peoria	Wet ground
<u>Habenaria leucophaea</u>	E	DuPage, Fulton, Peoria	Wet meadows
<u>Hudsonia tomentosa</u>	E	Fulton	Sandy soil
<u>Hydrastis canadensis</u>	T	DuPage, Fulton Peoria	Woods
<u>Lathyrus ochroleucus</u>	T	DuPage	Woods
<u>Lespedeza leptostachya</u>	E	DuPage	Prairie soil
<u>Microseris cuspidata</u>	E	Peoria	Dry prairies
<u>Mimulus glabratus</u>	E	Peoria	Wet ground
<u>Orobancha fasciculata</u>	E	Peoria	Sandy soil
<u>Oryzopsis racemosa</u>	T	Peoria	Rocky woods
<u>Panax quinquefolius</u>	T	Douglas, DuPage, Fulton, Peoria	Rich woods
<u>Panicum columbiana</u>	E	DuPage	Sandstone outcrops and sand deposits

Table D.6. Continued

Species	Status ^a	County	Habitat
<u>Plantago cordata</u>	E	DuPage, Peoria	Along ditches
<u>Poa wolfii</u>	E	Fulton, Peoria	Woodlands
<u>Polygala incarnata</u>	E	Fulton, Peoria	Prairie soil
<u>Polygonatum pubescens</u>	E	DuPage	Woods
<u>Ranunculus ambigens</u>	E	Fulton	Swamps and ditches
<u>Ranunculus cymbalaria</u>	E	DuPage	Wet, sandy soil
<u>Rhamnus alnifolia</u>	E	Peoria	Wooded swamps
<u>Rhynchospora alba</u>	T	Peoria	Bogs
<u>Rorippa islandica</u> var. <u>hispida</u>	E	DuPage	Wet ground
<u>Sabatia campestris</u>	E	DuPage, Peoria	Prairie soil
<u>Scheuchzeria palustris</u>	E	Fulton	Bogs
<u>Scirpus smithii</u>	E	Peoria	Wet shores
<u>Sparganium americanum</u>	E	DuPage	Ditches
<u>Spiranthes romanzoffiana</u>	E	Peoria	Floating sedge mat
<u>Tradescantia bracteata</u>	E	Peoria	Prairie soil
<u>Trifolium reflexum</u>	E	Fulton, Peoria	Woods and fields
<u>Triglochin maritima</u>	E	Peoria	Sandy or marly swales, swamps or along ditches
<u>Triglochin palustris</u>	E	Peoria	Calcareous soil
<u>Veronica americana</u>	E	DuPage, Peoria	Swampy ground
<u>Veronica scutellata</u>	T	DuPage, Fulton, Peoria	Along ditches and ponds
<u>Viburnum molle</u>	E	Peoria	Bluffs and rocky woods
<u>Viola vlarum</u>	E	Peoria	Gravelly areas

^a E = Endangered; T = Threatened.

Sources: Jones (1963); Natural Land Institute (1981).

Table D.7. Illinois-Listed Endangered and Threatened Plant Species with Extant Populations Occurring in Counties Where Potential Alternative Disposal Sites are Located

Species	Status ^a	County	Habitat	Locations in Illinois
Polypodiaceae				
<u>Thelypteris phegopteris</u> (Long beech fern)	E	Fulton	Moist, shaded sandstone cliffs; ravines; woods	State nature preserves and state parks
Cupressaceae				
<u>Thuja occidentalis</u> (Arbor vitae)	T	Fulton	Sandstone and limestone cliffs, fens, marshes, bogs	State nature preserves and private lands
Pinaceae				
<u>Pinus resinosa</u> (Red pine)	E	Fulton	Sandstone river bluffs	Single Illinois population occurs on private land
Cyperaceae				
<u>Carex crawei</u> (Sedge)	E	DuPage	Moist calcareous soil, sandy soil	University research area, county forest preserve, state park, and private land
<u>Scirpus paludosus</u> (Alkali bulrush)	E	Fulton	Saline marshes, wet ground	Occurs on private land
Orchidaceae				
<u>Corallorhiza maculata</u> (Spotted coral-root orchid)	T	DuPage	Mesic to xeric forests	State nature preserve, county forest preserves, institutional preserve, and private land
<u>Cypripedium candidum</u> (White lady's slipper)	E	DuPage	Calcareous wet-mesic prairies, fens, bogs, swamps	State nature preserves and a county forest preserve
<u>Habernaria leucophaea</u> (Prairie white fringed orchid)	E	DuPage	Mesic and wet prairies	County forest preserves, state park, and other areas given various degrees of protection
Araliaceae				
<u>Panax quinquefolius</u> (Ginseng)	T	Douglas, DuPage, Fulton, Peoria	Rich mesic woodlands	Many locations statewide
Caprifoliaceae				
<u>Sambucus pubens</u> (Red-berried elder)	T	Fulton	Moist, rocky wooded slopes; bogs	State parks and private land
<u>Viburnum molle</u> (Arrowwood)	E	Peoria	Wooded hillsides, limestone bluffs	Private land

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Table D.7. Continued

Species	Status ^a	County	Habitat	Locations in Illinois
Caryophyllaceae				
<u>Arenaria patula</u> (Slender sandwort)	T	DuPage	Barrens, dolomite outcrops, open woods, disturbed sites, wooded slopes along streams	County forest preserve and private land
Compositae				
<u>Artemisia dracunculus</u> (False tarragon)	E	Peoria	Dry sand and gravel, excavations, pastures, prairie soils	County forest preserve and, possibly, on bluffs along the Illinois and Sangamon rivers
<u>Aster schreberi</u> (Schreber's aster)	T	Peoria	Rich, wooded ravines	State nature preserves and county forest preserve
<u>Solidago sciaphila</u> (Cliff goldenrod)	T	Fulton	Moist, shaded or exposed dolomite and sandstone cliffs; sandy woods	State parks and private land
Leguminosae				
<u>Lespedeza leptostachya</u> (Prairie clover)	E	DuPage	Dry gravel and sand prairies	Roadside managed as a prairie, private lands (two of which are threatened by grazing and another at the rim of a quarry)
Ranunculaceae				
<u>Hydrastis canadensis</u> (Golden seal)	T	DuPage	Mesic and wet-mesic upland forests	A number of locations statewide
Rosaceae				
<u>Filipendula rubra</u> (Queen-of-the-prairie)	T	Fulton	Fens, mesic sand prairies, seeps, moist gravel	State nature preserve, county forest preserve, state land, and private land
Scrophulariaceae				
<u>Veronica scutellata</u> (Marsh speedwell)	T	DuPage	Marshes, pond shores, springy sites along ditches	Forest preserves, conservation area, and private land

^a E = endangered; T = Threatened.

Sources: Natural Land Institute (1981); additional habitat data from Jones (1963).

Table D.8. Chronology of Vegetational Succession on the Waste Cover under Passive Maintenance

0-10 years	Seeding of grass should be done as soon as surfaces are available. Spontaneous woody plant species will appear in the grass cover. Shrub species will be grey dogwood, smooth sumac, staghorn sumac, and hazelnut. Young saplings of tree species will appear.
10-25	Increasing numbers of trees will develop into loose thickets, associated with spreading clumps of shrubs. Tree species will be black cherry, box elder, Siberian elm, American elm, green ash, cottonwood, hawthorn, mulberry, and hackberry.
25-50	Growth of thicket tree species will produce shade and a layer of fallen leaves each year. Diameters of thicket trees will increase beyond the 6-in. size as the thicket becomes somewhat forest-like. Saplings of young white ash, linden, red elm, and ironwood may spontaneously occur.
50-100	Forest-like conditions will continue to develop as trees increase in size to diameters exceeding 12 in. Annual autumn leaf drop will make a significant contribution to the forest floor as humus develops. Sponge-like adsorption of precipitation will become more and more effective. Sugar maple and red oak saplings may appear.
100-200	Forest dynamics will exhibit slow changes as competition for space involves larger and larger trees. Successful competitors will emerge as trees that may endure for two or more centuries become part of a nearly stable forest system. Increasingly important species are likely to be linden, white ash, red elm, red oak, ironwood, and sugar maple. Shrubs and wildflowers associated with stable native regional forest systems should become abundant.
200-500	Slow changes in forest composition will tend toward increasing dominance of shade-tolerant species. The components will be the same as those of the 100- to 200-year time span, but an increase in the size and importance of sugar maple will become evident. Flora of the forest floor should be diverse.
500-1000	Increasing dominance of sugar maple will continue. Associates, though perhaps in small numbers, will still be those species listed in the 100- to 200-year stage. A thick porous organic forest soil should be present.

Source: Ware (1986).

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APPENDIX E. GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELING

APPENDIX E. GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELING

E.1 MODEL DESCRIPTION

The migration of radionuclides and nonradioactive chemicals for the potential disposal sites was simulated using a modified solute transport code, AT123D, which was originally developed at Oak Ridge National Laboratory (Yeh 1981). AT123D solves the following solute transport equation analytically for a homogeneous medium under saturated conditions:

$$\frac{\partial C}{\partial t} = \frac{D_{xx}}{Rd} \frac{\partial^2 C}{\partial x^2} + \frac{D_{yy}}{Rd} \frac{\partial^2 C}{\partial y^2} + \frac{D_{zz}}{Rd} \frac{\partial^2 C}{\partial z^2} - \frac{v}{Rd} \frac{\partial C}{\partial x} - \lambda C + \frac{\dot{M}}{n_e Rd} \quad (E.1)$$

where C is the dissolved concentration of the solute; D_{xx} , D_{yy} , D_{zz} are the longitudinal, transverse, and vertical dispersion coefficients; Rd is the retardation factor; v is the average pore water velocity; λ is the radioactive decay constant; $\dot{M}$ is the source release rate; and n_e is the effective porosity. For the Proposed Action (on-site disposal) and Alternative D (farmland disposal), wastes would be situated in the unsaturated zone above the groundwater table. Hence, AT123D was modified so that it could handle saturated-unsaturated conditions. The source input option of AT123D was modified by incorporating a transient waste-leaching model. The retardation factor used in the AT123D was also modified. Detailed descriptions of the modifications follow.

E.1.1 Saturated-Unsaturated Media

The transport media for the Proposed Action and Alternative D sites may be illustrated as shown in Figure E.1. The modification to AT123D was a travel-time method described by Gilbert et al. (1983). The waste field was assumed to be a rectangular block with dimensions L_x , L_y , and L_z . The geometry of the contaminated layer was assumed to remain constant during vertical migration in the unsaturated zone. Precipitation falling on the waste field would infiltrate through the wastes and transport contaminants down through the unsaturated (vadose) zone into the saturated (aquifer) zone. After the contamination reached the water table, it would spread out, be diluted in the groundwater, and generate a contaminant plume that would move in the downgradient direction.

The travel-time method can handle layered soil conditions in the unsaturated zone. The travel time, i.e., the time for contaminants to transport through the unsaturated zone, for an n-layered zone was calculated as

$$T_d = \sum_{j=1}^N L_j \theta_j Rd_j / I \quad (E.2)$$

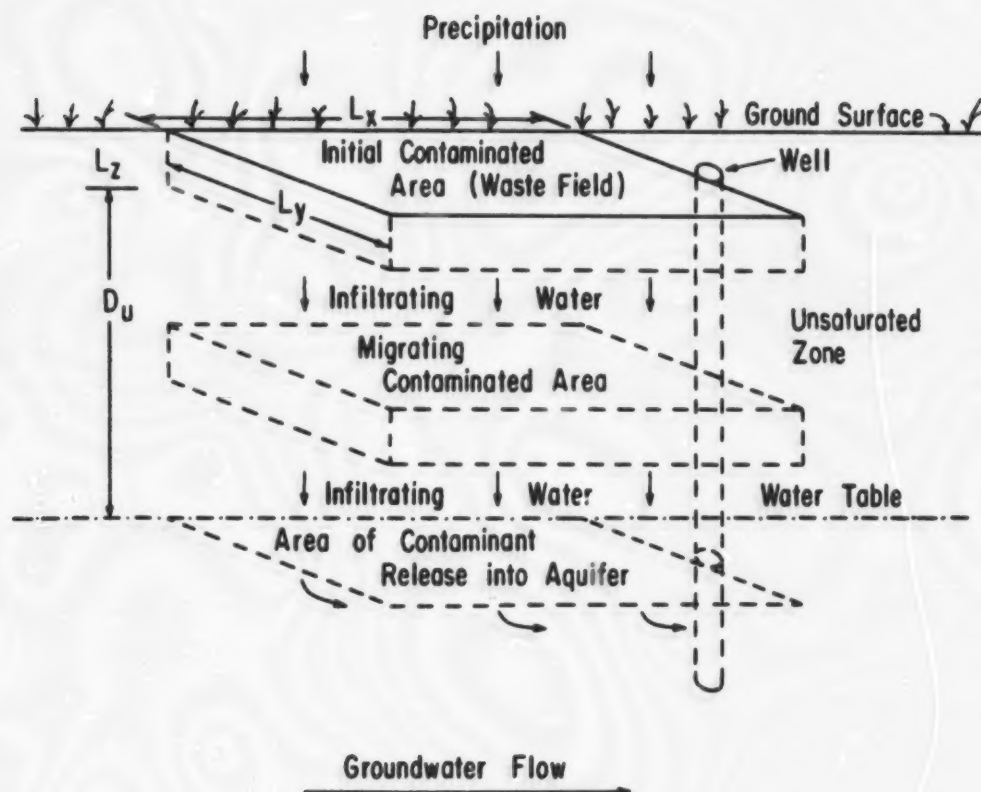


Figure E.1. Schematic Diagram of Model for Existing Contaminant Concentrations in Groundwater for the Proposed Action and Alternative D.

Source: Modified from U.S. Department of Energy (1986).

where T_d is the travel time, L_j is the j th layer thickness, θ_{e_j} is the j th layer effective moisture content, Rd_j is the j th layer retardation factor, and I is the infiltration rate. The retardation factor is discussed in Section E.1.3. Radioactive decay during transport through the unsaturated zone was considered in calculating the source term by incorporating a correction factor.

For Alternatives A, B, and C, the waste fields would be below the water table. Hence, the travel-time method was not used for these alternatives.

E.1.2 Transient Waste Leaching

The waste release rate (source strength) was calculated using a first-order leaching rate (exponential leaching) model (Baes and Sharp 1983). The source strength, $\dot{Q}(t)$, can be written as:

$$\dot{Q}(t) = \lambda_l \cdot \rho_b \cdot V \cdot C_d(t) \quad (E.3)$$

where λ_l is the solute (radionuclide or nonradioactive chemical) leach rate, ρ_b is the waste density, V is the waste volume, and $C_d(t)$ is the solute concentration at time t . The solute leach rate, λ_l , can be calculated as (Baes and Sharp 1983):

$$\lambda_l = \frac{I}{\theta_e L_z R_d} \quad (E.4)$$

where I is the infiltration rate if the wastes are in the unsaturated zone or the Darcy velocity if the wastes are in the saturated zone, θ_e is the effective moisture content in the wastes, L_z is the waste leaching thickness, and R_d is the solute retardation factor. The effective moisture content, θ_e , in Equation E.4 is the product of effective porosity, n_e , and the moisture saturation ratio, R_s , which is defined as the fraction of the voids in a porous medium that is filled with water. The retardation factor is discussed in Section E.1.3. The solute concentration at any time t , $C_d(t)$, is obtained by solving the following two differential equations:

$$\frac{dC_p(t)}{dt} = -(\lambda_p + \lambda_{lp}) C_p(t) \quad (E.5)$$

$$\frac{dC_d(t)}{dt} = -(\lambda_d + \lambda_l) C_d(t) + \lambda_d C_p(t) \quad (E.6)$$

where $C_p(t)$ is the parent nuclide concentration, λ_p is the parent decay constant, λ_{lp} is the parent leach rate, and λ_d is the daughter (nuclide of interest) decay constant. For radioactive nuclides, only uranium-238 and radium-226 need to be analyzed in this document (see Section E.2). For uranium-238, $C_p(t)$, λ_p , and λ_{lp} are all zero. For radium-226, the leaching of thorium-230 (the parent nuclide of radium-226) may be neglected because thorium-230 has a relatively high distribution coefficient of about 60,000 mL/g (Gilbert et al. 1983). Therefore, Equation E.5 reduces to

$$\frac{dC_p(t)}{dt} = -\lambda_p C_p(t) \quad (E.7)$$

Solving Equations E.6 and E.7 with initial source concentrations (pCi/g) of S_p and S_d for parent and daughter nuclides respectively, one obtains:

$$C_d(t) = S_d e^{-(\lambda_l + \lambda_d)t} + \frac{\lambda_d S_p}{\lambda_l + \lambda_d - \lambda_p} [e^{-\lambda_p t} - e^{-(\lambda_l + \lambda_d)t}] \quad (E.8)$$

E.1.3 Retardation Factor

The retardation factor was defined in AT123D as:

$$R_d = 1 + \rho_b K_d / n_e \quad (E.9)$$

where ρ_b is the bulk density of the medium, K_d is the distribution coefficient, and n_e is the effective porosity. Use of this R_d underestimates the solute migration rate if the transport medium contains either micropores or macropores. Based on the Group-Transfer Concept (GTC) developed at the Pennsylvania State University (Yu 1984), the bulk density in Equation E.9 should be replaced by an effective density, which is defined as the quotient of the solid mass in the effective region divided by the bulk volume. Because the solid mass in the effective region is always less than or equal to the bulk mass, the retardation factor calculated using Equation E.9 is an overestimate (i.e., nonconservative). An alternative approach is therefore required.

The GTC model defines the retardation factor for an arbitrary group, group i (e.g., homogeneous media excluding dead-end pores), as (Yu 1984)

$$R_{d_i} = 1 + \frac{f_i \rho_i}{\theta_i} K_{d_i} \quad (E.10)$$

where f_i is the fraction of bulk volume associated with group i , ρ_i is the bulk density of the medium associated with group i , θ_i is the volumetric water content in group i , and K_{d_i} is the distribution coefficient for group i . It can be shown (Yu 1984) that

$$\sum_{i=1}^n f_i \rho_i = \rho_b \quad (E.11)$$

and

$$\sum_{i=1}^n \theta_i = \theta_t \quad (E.12)$$

where n is the total number of groups and θ_t is the total water content in the medium. Because the application of AT123D to a medium containing micropores or macropores was essentially the same as using the single group option of the

GTC model to solve a multigroup (medium containing micropores/macropores) problem, a set of effective parameters should be chosen to reflect this effect and obtain conservative estimates of contaminant concentrations. Because $f_1 \rho_1 = \rho_b$ when $n = 1$ (single group), therefore $\theta_1 = \theta_t$. That is,

$$R_d = 1 + \frac{\rho_b}{\theta_t} \quad K_d = 1 + \frac{\rho_b K_d}{n_t R_s} \quad (E.13)$$

where n_t and R_s are the total porosity and saturation ratio of the medium, respectively.

Equation E.13 is a more conservative way of calculating the retardation factor than Equation E.9 when using Equation E.1 to estimate contaminant concentrations in a medium containing macropores or fractures. Equation E.13 has been incorporated in the modified version of AT123D. The modified AT123D will be referred to as MAT123D in the remaining discussions.

E.2 SOURCE TERM

The source term is a major factor in determining the radionuclide concentrations in a groundwater system. Because of the high retardation for thorium and the relatively short half-life of radium-228 and other radionuclides in the wastes (see Section 5.9), it was concluded that the only radionuclides that needed to be analyzed individually to estimate radiological impacts were uranium-238 and radium-226. The ingrowth of radium-226 from thorium-230 was considered in the source leaching term (see Section E.1.2). The concentration of uranium-234 was assumed to be equal to the concentration of uranium-238.

The source concentrations of radionuclides in the wastes that were used in the MAT123D model were 73 pCi/g for uranium-238, 33 pCi/g for thorium-230, and 69 pCi/g for radium-226. These source terms were the average radionuclide concentrations calculated from data given in Chapter 2, Tables 2.2 and 2.4. The source strength (contaminant release rate) was calculated in MAT123D using the method described in Section E.1.2.

Data on concentrations of chemical species in the different waste components are limited and are available for some chemical species in some waste components. The data, which are summarized in Table 2.5, were used as follows. A weighted average concentration for each chemical species was calculated for the ore tailings, sludge pile, and pond 1 and pond 2 sediments using the concentrations in Table 2.5 and the mass fractions obtained from data in Table 2.2. (The concentrations for ponds 3, 4, and 5 were assumed to be the same as that given for pond 2 in Table 2.5). The conservative assumption was then made that the weighted average concentrations obtained apply to all the wastes, and they were used as the average concentrations for all the wastes. These averages are given in Table E.1.

Table E.1. Estimated Average Concentrations and Representative Kd Values for the Kerr-McGee Wastes^a

Chemical Species	Average Concentration (ppm)	Representative Kd value (mL/g) ^b
Antimony	16	3
Arsenic	2.0	3
Cadmium	0.75	3
Chromium	15	25
Copper	28	25
Lead	730	100
Mercury	1.1	100
Nickel	14	1,000
Selenium	<63 ^c	3
Silver	4.1	100
Zinc	90	25
Cyanide	1.6 ^d	0 ^e

^a Values rounded to two significant figures.

^b See Section E.3 for explanation of how values were obtained.

^c Value determined from upper limits given in Table 2.5.

^d Value obtained from Table 2.5 for pond 2 sediments. Values given in Table 2.5 as upper limits for the other waste components were not used because they are not meaningful.

^e Sources: Fuller (1977); Theis and West (1986).

E.3 HYDROLOGIC AND GEOCHEMICAL PARAMETER VALUES

The hydrogeologic parameter values used in the MAT123D model for calculating contaminant migration at the West Chicago and alternative sites are listed in Table E.2. These parameters were selected to generate conservative estimates of contaminant concentrations in groundwater. The hydrogeologic flow parameters -- such as precipitation, evapotranspiration, hydraulic gradient, hydraulic conductivity, effective porosity, total porosity, unsaturated zone depth, and various dispersivities -- were obtained primarily from site-specific reports for the West Chicago site (FES; Zeizel et al. 1962; Law Eng. Test Co. 1981a, 1981b; Kerr-McGee 1986--Vol. II). When site-specific data were not available, generic values were used (Geraghty et al. 1973; T111

Table E.2. Parameters Used in the MAT123D Model^a

Parameter	Symbol	Unit ^b	Proposed Action	Alternative			
				A	B	C	D
Annual precipitation	P	m/yr	0.88	£/	£/	£/	0.85
Evapotranspiration rate	E	m/yr	0.63	£/	£/	£/	0.61
Infiltration rate	I	m/yr	0.03	£/	£/	£/	0.03
Total porosity:	n_t	-					
Wastes			0.23	0.23	0.23	0.23	0.23
Unsaturated zone			0.42	£/	£/	£/	0.42
Saturated zone			0.40	0.42	0.42	0.42	0.42
Effective porosity:	n_e	-					
Wastes			0.23	0.23	0.23	0.23	0.23
Unsaturated zone			0.06	£/	£/	£/	0.06
Saturated zone			0.25	0.06	0.06	0.20	0.06
Dry bulk density:	ρ_b	kg/m ³					
Wastes			1,500	1,500	1,500	1,500	1,500
Unsaturated zone			1,800	£/	£/	£/	1,800
Saturated zone			1,500	1,800	1,800	1,900	1,800
Hydraulic gradient	I	-	0.01	0.01	0.01	0.01	0.01
Hydraulic conductivity	K	m/yr	2.1×10^4	87	10	100	10
Longitudinal dispersivity	α_L	m	30	1.0	1.0	1.0	1.0
Transverse dispersivity	α_T	m	3	0.1	0.1	0.1	0.1
Vertical dispersivity	α_V	m	3	0.1	0.1	0.1	0.1
Unsaturated zone depth	D_u	m	1.0	£/	£/	£/	0
Saturation ratio:	R_s	-					
Wastes			0.5	1.0	1.0	1.0	0.5
Unsaturated zone			0.5	£/	£/	£/	0.5
Saturated zone			1.0	1.0	1.0	1.0	1.0
Distribution coefficient:	Kd	mL/g					
Uranium--							
Wastes			50	50	50	50	50
Unsaturated zone			50	£/	£/	£/	50
Saturated zone			4.0	50	50	50	50
Radium--							
Wastes			100	100	100	100	100
Unsaturated zone			100	£/	£/	£/	100
Saturated zone			10	100	100	100	100

^a Parameters reported to two significant figures.^b A hyphen means that the parameter is dimensionless.^c Parameter is not required because the medium is a saturated zone.

and Meyer 1983; Natl. Counc. Radiat. Prot. Measure. 1984; Sheppard et al. 1984). For example, the hydraulic conductivity values for the Alternative A and B sites were site-specific (Midland Coal Co. 1984) whereas the values for the Alternative C and D sites were estimates based on the properties of the on-site soils.

The waste-field dimensions used in MAT123D for the analysis of the West Chicago and alternative sites are shown in Table E.3. The waste-field was assumed to be a rectangular block with a volume equal to the total volume of the wastes. The dimensions of the waste field were calculated based on the disposal cell designs discussed in Appendix B.

Table E.3. Dimensions of the Waste Field Used in the MAT123D Model^a

Alternative	L _x (m)	L _y (m)	L _z (m)
Proposed Action	150	250	7.5
A	43	470	14
B	43	470	14
C	550	440	1.2
D	340	340	2.4

^a Values are reported to two significant figures.

The distribution coefficients for radionuclides in various soil conditions are given in Table E.2. For many chemical species, the measured values of the distribution coefficients (K_d values) vary over a wide range because they depend on such factors as the oxidation state of the species, the properties of the soil/rock matrix, and the chemical content and pH of the water. Mean values and associated standard deviations for K_d values for some chemical elements in soil and clay have been given by Baes and Sharp (1983) and by Nuclear Safety Associates (1980) (for mercury and nickel). These values were grouped together, and one representative value was chosen for each group and assigned to all chemical species in the group. This choice of representative K_d values is supported by the fact that, for each chemical species, the range of values determined by the mean and standard deviation includes the representative value; these values are given in Table E.1. K_d values in sandy soil, such as the E stratum materials under the West Chicago site, were assumed to be 10% of the values given in Table E.1 (Nucl. Saf. Assoc. 1980).

E.4 MODELING RESULTS

E.4.1 Travel Time

The travel time for water and radionuclides to move through the unsaturated zone was calculated using Equations E.2 and E.13 (for water, R_d equals unity). For Alternatives A, B, and C, the wastes would be situated in the saturated zone. For Alternative D, the wastes could be situated right above the water table (see Appendix B). Hence, only the Proposed Action (West Chicago) would have a nonzero travel time. For the West Chicago site, the calculated water travel time is 1 year and the calculated radionuclide travel times are 430 years for uranium-238 and 860 years for radium-226. The radionuclide travel times are greater than the water travel time due to the sorptive properties of soil.

E.4.2 Radionuclide Concentrations in Groundwater

The time and spatial variations of radium-226 and uranium-238 concentrations in groundwater were calculated using the MAT123D model. The maximum concentrations and the time to reach the maximum concentration of radium-226 and uranium-238 at a hypothetical well at the waste field boundary and at the site boundary downgradient from the waste field are presented in Tables E.4 and E.5, respectively. The concentrations of radium-226 and uranium-238 in groundwater at 1,000 years after waste emplacement are presented in Table E.6.

The concentrations of uranium-238 and radium-226 at the site boundary within 1,000 years are predicted by the model to be below the U.S. Nuclear Regulatory Commission (NRC) limits (10 CFR Part 20) of 30 pCi/L for radium-226 and 40,000 pCi/L for uranium-238 for the Proposed Action and all alternatives. They are also predicted to be below the U.S. Department of Energy (DOE) limits (DOE Order 5480.1A--DCG for unrestricted use) of 100 pCi/L for radium-226 and 600 pCi/L for uranium-238 and the U.S. Environmental Protection Agency (EPA) standard (40 CFR Part 141) of 5 pCi/L for radium-226. Except for Alternative A, the concentrations are predicted to be below the recommended level of 40 pCi/L for uranium-238 (Cothorn et al. 1983; U.S. Environ. Prot. Agency 1986); the uranium-238 concentration at the site boundary for Alternative A is predicted to be 40 pCi/L at 1,000 years after waste emplacement. The predicted radium-226 concentrations for the Proposed Action and all alternatives at the site boundary within 1,000 years are also predicted to be below the state of Illinois limit of 1 pCi/L (no state limit is set for uranium-238) (35 Ill. Adm. Code Part 302).

The radionuclide concentrations in hypothetical on-site wells are all predicted by the model to be below DOE limits (DOE Order 5480.1A) and NRC limits (10 CFR Part 20) in the 1,000-year period. Only the Proposed Action

Table E.4. Predicted Radionuclide Concentrations in Hypothetical On-site Wells^a

Alternative ^b	Uranium-238		Radium-226	
	Maximum Concentration (pCi/L)	Time to Reach Maximum Concentration (yr)	Maximum Concentration (pCi/L)	Time to Reach Maximum Concentration (yr)
Proposed Action	0.33	450 ^c	0.11	900 ^c
A	73	800	23	1,300
B	75	6,900	4.5	4,200
C	>14 ^d	>10,000 ^d	1.0	3,000
D	150	6,200	23	2,300

^a Wells are assumed to be located at the midpoint of the downgradient edge of the waste containment area.

^b Parameters used are listed in Table E.2.

^c Includes the travel time of 430 years for uranium-238 and 860 years for radium-226.

^d Maximum concentration was not reached in the simulation time of 10,000 years. The concentration at year 10,000 is reported here.

and Alternative C would have radionuclide concentrations in on-site wells at 1,000 years that are below the EPA limits (40 CFR Part 141) of 5 pCi/L radium-226 and the recommended level of 40 pCi/L for uranium-238 (Cothorn et al. 1983; U.S. Environ. Prot. Agency 1986). The radium-226 concentrations in on-site wells at 1,000 years for the Proposed Action and Alternative C would also be below the state of Illinois limit of 1 pCi/L (35 Ill. Adm. Code Part 302).

E.4.3 Chemical Concentrations in Groundwater

Peak groundwater concentrations occurring within the 1,000-year period following site closure and the time of occurrence of the peak concentrations downgradient from the waste pile are given for some chemical species in Table E.7. The concentration values are the contributions from leaching of the wastes only and do not include background contributions. The values for the waste pile edge and downgradient points are maxima values in cross sections of the groundwater contaminant plume, and they apply to the uppermost aquifer. For example, for the Proposed Action, the values in Table E.7 are the concentrations for groundwater at the top of the water table in the E stratum.

Table E.5. Radionuclides in Groundwater at the Site Boundary
Downgradient from the Waste Field

Alternative ^a	Distance ^b from Site (m)	Uranium-238		Radium-226	
		Maximum Concentration (pCi/L)	Time to Reach Maximum Concentration (yr)	Maximum Concentration (pCi/L)	Time to Reach Maximum Concentration (yr)
Proposed Action	100	0.33	450 ^c	0.11	900 ^c
A	46	68	1,500	12	2,800
B ^d	46	>51	>10,000	>0.013	>10,000
C ^d	46	>9.2	>10,000	>0.092	>10,000
D ^d	46	>63	>10,000	>0.024	>10,000

^a Parameters used are listed in Table E.2.

^b The distance between the downgradient site boundary and the nearer waste field boundary.

^c Includes the travel time of 430 years for uranium-238 and 860 years for radium-226.

^d Maximum concentration was not reached in the simulation time of 10,000 years. The concentration at year 10,000 is reported here.

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Table E.6. Radionuclide Concentrations at 1,000 Years after Waste Emplacement

Alternative ^a	Concentration (pCi/L)			
	On-site Well ^b		Site Boundary ^c	
	Uranium-238	Radium-226	Uranium-238	Radium-226
Proposed Action	0.32	0.10	0.32	0.10
A	70	21	40	0.15
B	15	2.5	0	0
C	3.6	0.72	0	0
D	83	20	0	0

^a Parameters used are listed in Table E.2.

^b On-site well was assumed to be located next to the disposal cell area.

^c Site boundary is downgradient from the waste field (see Table E.5 for site boundary distance).

According to the model results (Table E.7), peak concentrations in the groundwater in the 1,000-year period are predicted to be much lower (by factors of more than 10) for the Proposed Action than for Alternatives A-D. This is mainly due to the fact that the pore water velocity and diffusion coefficient for the groundwater are much higher at the West Chicago site than at the other disposal sites, which results in more diffusion and dilution of leachate in the groundwater at the West Chicago site than at the other sites.

West Chicago Site (Proposed Action). For the Proposed Action, peak concentrations in the groundwater at the midpoint of the downgradient waste pile edge are predicted to occur within the 1,000-year period for all chemical species listed in Table E.7. Peak concentrations for all modeled chemical species for the Proposed Action would be below the EPA groundwater protection standards and the Illinois general use water quality standards. Lead would have a peak concentration of 1.4 µg/L at the waste pile edge and 1.5 µg/L at 100 m downgradient, both occurring in about 900 years; these concentrations are 2.8% and 3.0% of the EPA groundwater protection standard of 50 µg/L (Table 2.8). The concentration of cyanide at the waste pile edge would be 3.3 µg/L, which is 13% of the Illinois general use water quality standard of 25 µg/L (Table 2.9). All other species would have peak concentrations that are less than 1% of the EPA and Illinois water quality standards. Selenium is discussed at the end of this section.

Table E.7. Peak Chemical Concentrations and Times of Occurrence
at the Downgradient Positions within the 1,000-Year Period^a

Chemical Species	Proposed Action	Peak Concentration ($\mu\text{g/L}$) at Midpoint of Downgradient Waste Pile Edge			
		Alt. A	Alt. B	Alt. C	Alt. D
Antimony	0.97	290	290	110	420
Arsenic	0.12	36	36	15	53
Cadmium	0.045	14	14	5.5	19
Chromium	0.10	32	19	5.8	34
Copper	0.18	59	36	11	64
Lead	1.4	400	53	24	200
Mercury	0.0021	0.61	0.080	0.035	0.30
Selenium	<3.8	<1,100	<1,100	<460	<1,700
Silver	0.0080	2.3	0.30	0.13	1.1
Zinc	0.59	190	110	35	200
Cyanide	3.3	550	560	220	980

Chemical Species	Proposed Action (100 m)	Peak Concentration ($\mu\text{g/L}$) at Various Downgradient Distances ^b			
		Alt. A (70 m)	Alt. B (70 m)	Alt. C (200 m)	Alt. D (300 m)
Antimony	1.1	200	240	49	0
Arsenic	0.13	25	30	6.1	0
Cadmium	0.047	9.3	11	2.3	0
Chromium	0.12	29	0 ^c	0	0
Copper	0.23	54	0	0	0
Lead	1.5	0	0	0	0
Mercury	0.0023	0	0	0	0
Selenium	<4.2	<780	<960	<190	0
Silver	0.0082	0	0	0	0
Zinc	0.73	170	0	0	0
Cyanide	4.2	460	460	130	300

Table E.7. Continued

Chemical Species	Proposed Action	Time of Peak Occurrence (yr) at Midpoint of Downgradient Waste Pile Edge ^d			
		Alt. A	Alt. B	Alt. C	Alt. D
Antimony	29	35	300	800	600
Arsenic	29	35	300	800	600
Cadmium	29	35	300	800	600
Chromium	220	260	1,000	1,000	1,000
Copper	220	260	1,000	1,000	1,000
Lead	890	1,000	1,000	1,000	1,000
Mercury	890	1,000	1,000	1,000	1,000
Selenium	29	35	300	800	600
Silver	890	1,000	1,000	1,000	1,000
Zinc	220	260	1,000	1,000	1,000
Cyanide	1.6	2.4	21	53	16

Chemical Species	Proposed Action (100 m)	Time of Peak Occurrence (yr) at Various Downgradient Distances ^{b,d}			
		Alt. A (70 m)	Alt. B (70 m)	Alt. C (200 m)	Alt. D (300 m)
Antimony	29	100	950	1,000	1,000
Arsenic	29	100	950	1,000	1,000
Cadmium	29	100	950	1,000	1,000
Chromium	230	900	1,000	1,000	1,000
Copper	230	900	1,000	1,000	1,000
Lead	890	1,000	1,000	1,000	1,000
Mercury	890	1,000	1,000	1,000	1,000
Selenium	29	100	950	1,000	1,000
Silver	890	1,000	1,000	1,000	1,000
Zinc	230	900	1,000	1,000	1,000
Cyanide	1.8	7.6	67	97	250

^a Values rounded to two significant figures.

^b Distances are measured from downgradient edge of the waste pile.

^c A zero means that the contamination has not reached the downgradient distance from the waste pile edge in 1,000 years.

^d Values represent time of peak occurrence or 1,000 years, whichever is less.

Other Disposal Sites (Alternatives A, B, C, and D). For Alternatives A-D, peak concentrations of one or more chemical species in the groundwater are predicted to exceed the EPA and Illinois water quality standards at the edge of the waste pile within 1,000 years. Peak concentrations of copper, lead, and cadmium in groundwater at the edge of the waste pile are predicted to exceed either the Illinois general use water quality standards or the EPA groundwater protection standards (Tables 2.8 and 2.9) for Alternatives A, B, and D. Concentrations of copper would reach the Illinois general use water quality standard in less than 100 years for Alternative A, about 600 years for Alternative B, and about 170 years for Alternative D. Peak concentrations of arsenic for Alternative D are predicted to reach 53 $\mu\text{g/L}$, which is above the EPA groundwater protection standard of 50 $\mu\text{g/L}$ (Table 2.8), in 600 years. Peak concentrations of cyanide at the waste pile edge are predicted to reach 550 $\mu\text{g/L}$ for Alternative A, 560 $\mu\text{g/L}$ for Alternative B, 220 $\mu\text{g/L}$ for Alternative C, and 980 $\mu\text{g/L}$ for Alternative D -- all above the Illinois general use water standard of 25 $\mu\text{g/L}$. These peak concentrations would be reached in 2.4 years for Alternative A, 21 years for Alternative B, 53 years for Alternative C, and 16 years for Alternative D. Peak concentrations of mercury at the downgradient waste pile edge are predicted to reach 0.61 $\mu\text{g/L}$ in 1,000 years for Alternative A, above the Illinois general use standard of 0.5 $\mu\text{g/L}$ (Table 2.9).

Of the chemical species listed in Table E.7, only cadmium, copper, and cyanide are predicted to reach peak concentrations above either the Illinois general use water quality standards or the EPA groundwater protection standards at the listed downgradient distances within the 1,000-year period. The concentration of cadmium at 70 m downgradient would be 11 $\mu\text{g/L}$ in 950 years for Alternative B, above the EPA groundwater protection standard of 10 $\mu\text{g/L}$ (Table 2.8); the concentration of copper at 70 m downgradient would be 54 $\mu\text{g/L}$ in 900 years for Alternative A, above the Illinois general use standard of 20 $\mu\text{g/L}$ (Table 2.9). The concentrations of cyanide at the downgradient distances listed would be 460 $\mu\text{g/L}$ in 7.6 years for Alternative A, 460 $\mu\text{g/L}$ in 67 years for Alternative B, 130 $\mu\text{g/L}$ in 97 years for Alternative C, and 300 $\mu\text{g/L}$ in 250 years for Alternative D -- all above the Illinois general use standard of 25 $\mu\text{g/L}$ (Table 2.9). Concentrations of several species are predicted to be zero because 1,000 years is not sufficient time for these species to be transported in the groundwater for the downgradient distances listed in Table E.7. This is especially true for the less mobile species such as lead, mercury, and silver; however, these species would travel the 100 m distance in 1,000 years for the Proposed Action. Some other peak groundwater concentrations for Alternative A at the listed downgradient distances are: arsenic, 25 $\mu\text{g/L}$; cadmium, 9.3 $\mu\text{g/L}$; and chromium, 29 $\mu\text{g/L}$. Also, for Alternative B, arsenic would have a peak concentration of 30 $\mu\text{g/L}$.

(Table E.7). These concentrations are all between 50% and 100% of the respective EPA groundwater protection standards (Table 2.8). Concentrations such as these, which are a large fraction of the standard, may exceed the standard when background concentrations are included.

After reaching peak concentrations in the groundwater, the concentrations of cyanide would decrease with a time characteristic of the leach time. The predicted leach times for cyanide ($K_d = 0$) are 7.9 years for Alternative A, 69 years for Alternatives B and C, and 13 years for Alternative D. Peak concentrations of cyanide at the listed downgradient distances are predicted to fall below the Illinois general use water quality standard of 25 $\mu\text{g/L}$ (Table 2.9) in about 31 years for Alternative A, about 300 years for Alternative B, about 220 years for Alternative C, and about 410 years for Alternative D.

Selenium concentrations are not discussed even though the upper limit values given in Table E.7 are large and, for Alternatives A-D, are predicted to be considerably above the EPA groundwater protection standard of 10 $\mu\text{g/L}$ (Table 2.8). Selenium is not discussed because the source term concentration (Table E.1) is derived from concentrations that are given as upper limit values for some of the waste components (Table 2.5) and are so high that they are almost meaningless. It can be predicted, however, that the peak selenium concentrations at the downgradient waste pile edge will be below the Illinois general use water quality standard of 1,000 $\mu\text{g/L}$ (Table 2.9) for the Proposed Action and Alternative C.

E.4.4 Uncertainty of Predictions

The model predictions have certain degrees of uncertainty associated with them because of uncertainties in the input parameters. Sensitivity analyses show that the predicted groundwater concentrations are directly proportional to the concentrations in the wastes and are inversely proportional to the values of K_d (for $K_d > 0$). For example, if the source term concentrations were reduced by a factor of 10, peak concentration contributions would be reduced by a factor of 10. Such a reduction would result in peak concentrations that are below the EPA groundwater protection standards and the Illinois general use water quality standards for all chemical species considered except cyanide. Peak concentrations of cyanide would remain above the water quality standard at the edge of the waste pile and listed downgradient distances for Alternatives A, B, and D for some time. Predicted concentrations of cyanide could be reduced further by using a nonzero value of K_d . However, there is no evidence in the literature that the value of K_d is greater than 0 for cyanide (Fuller 1977; Theis and West 1986).

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APPENDIX F. DETAILS OF COST AND WORK FORCE ESTIMATES

APPENDIX F. DETAILS OF COST AND WORK FORCE ESTIMATES

F.1 PROPOSED ACTION - ABOVE-GRADE DISPOSAL CELL AT THE WEST CHICAGO SITE

Details of the cost estimates for implementation of the Proposed Action are given in Table F.1. For purposes of cost estimation, activities were divided into separate activity categories (underlined), each with one or more subcategories. Most of the line entries are already combinations of several activities. For example, for the clay entry under cell berm construction, the cost of \$12.44/yd³ includes a cost of \$10.37/yd³ for buying and loading at the pit, a 5-mile haul, placing and spreading with a 180-HP bulldozer, and \$2.07/yd³ for compaction.

The following assumptions were made for these estimates. All borrowed materials would be hauled from a source 5 miles away. The soils and clay would be compacted by a sheepsfoot roller with 4-in. lifts in two passes, and the sand/gravel and E stratum material would be compacted by a riding vibrating roller with 6-in. lifts in two passes. Contaminated soils, as E stratum sand/gravel, would be excavated using a 1.5-yd³ crawler-mounted backhoe, and piles of material would be excavated by a 1.5-yd³ front-end loader (wheel-mounted). The excavation of pond sediments includes a cost multiplier of 1.5 because the sediments are wet (Means Co. 1986). Backfilling and spreading would be done by a 105-HP bulldozer with a 150-ft haul included. Most hauling would be carried out by 12-yd³ dump trucks, with appropriate haul distances chosen for the Factory, Intermediate, and Disposal sites. Intrusion barriers would consist of random filter stone (riprap) dumped from trucks and placed by machine.

Several items appear in Table F.1 as blanks because sufficient data are not available to make cost estimates, including activities such as water pumping, drainage, treatment, and disposal activities. The cost of water handling can be appreciable, especially if large volumes must be treated to remove contaminants before being released. Although the costs of the activities for which sufficient data are not available to make cost estimates are expected to be different for the Proposed Action and its alternatives, the cost differences for these activities are expected to be small compared to the cost differences for other major activities. Thus, their omission is not expected to change significantly the relationship among the action period costs for the Proposed Action and its alternatives.

The unit costs given in Table F.1 include labor costs and the subcontractor's overhead and profit. The general contractor's fee of 10% includes items such as field supervision, main office expense, liability, and insurance and is the percent value recommended by Means Company (1986).

Table F.1. Details of Cost Estimates for Implementing the Proposed Action^a

Site Preparation	
Clear and grub Disposal Site, 27 acres @ \$2000/acre	\$54,000
Construct detention pond, 25,000 yd ³ @ \$3.66/yd ³	91,500
Construct access roads, 4,700 yd ² @ \$3.44/yd ²	16,200 ^b
Other	-- ^c
TOTAL, Site Preparation	\$162,000
Cell Floor Construction	
Clay liner, 48,000 yd ³ @ \$7.02/yd ³	\$337,000
Capillary barrier, 24,000 yd ³ @ \$5.66/yd ³	136,000
Leachate monitoring system	
Sand/gravel filter drain, 14,600 yd ³ @ \$10.04/yd ³	\$147,000
4" drain pipe, 7200 ft @ \$3.37/ft (fn d)	24,300
6" manifold pipe, 1500 ft @ \$4.08/ft (fn d)	6,100
6" riser, 300 ft @ \$28/ft (fn e)	8,400
	<u>\$186,000</u>
Geotextile, 43,800 yd ² @ \$9.00/yd ² (fn f)	394,000
TOTAL, Floor Construction	\$1,050,000
Cell Berm Construction	
Clay 152,000 yd ³ @ \$12.44/yd ³ (fn g)	\$1,890,000
Sand/gravel 30,600 yd ³ @ \$10.04/yd ³	307,000
Select fill	
Off-site borrow 68,700 yd ³ @ \$12.44/yd ³ (fn g)	\$855,000
On-site excavate 23,100 yd ³ @ \$6.85/yd ³	158,000
	<u>\$1,010,000</u>
Intrusion barrier 37,100 yd ³ @ \$21/yd ³	779,000
Geotextile 28,700 yd ² @ \$9.00/yd ² (fn f)	258,000
Topsoil	
Off-site 4,300 yd ³ @ \$11.04/yd ³	\$ 47,500
On-site 35,300 yd ³ @ \$6.85/yd ³	242,000
	<u>\$289,000</u>
TOTAL, Berm Construction	\$4,540,000
Waste Placement	
Factory Site	
Building rubble, 17,000 yd ³ @ \$2.98/yd ³ (fn h)	\$ 50,600
Soils, 183,000 yd ³ @ \$6.18/yd ³ (fn h)	1,130,000
TOTAL, Factory Site	\$1,180,000
Intermediate Site	
Soils, 7,500 yd ³ @ \$5.88/yd ³ (fn i)	\$44,100
Disposal Site	
Tailings pile, 24,500 yd ³ @ \$23.69/yd ³ (fns j,k)	\$580,000
Sludge pile, 5,000 yd ³ @ \$4.72/yd ³ (fn j)	23,600
Pond 2-5 sediments	
Steel sheets, 403 tons @ \$1856/ton (fn l)	\$748,000
Dewatering	-- ^f
Sediment excavation, 13,000 yd ³ @ \$7.13/yd ³ (fn j)	92,700
	<u>\$841,000</u>

Table F.1. Continued

Waste Placement (Continued)Pond 1 sediments

Steel sheets, 83 tons @ \$1,856/ton (fn l)	\$154,000
Dewatering	-- ^r
Sediment excavation, 27,000 yd ³ @ \$7.13/yd ³	<u>192,000</u>
	\$346,000
Contaminated soils, 35,000 yd ³ @ \$5.88/yd ³	206,000
Neighborhood soils, 35,000 yd ³ @ 5.88/yd ³ (fn l, m)	205,000
Sanitary plant soils, 11,800 yd ³ @ 5.88/yd ³ (fn l, m)	<u>69,000</u>
TOTAL, Disposal Site	\$1,740,000
TOTAL, Waste Placement	\$2,970,000

Temporary Cell Coverⁿ

Clay, 28,100 yd ³ @ \$12.44/yd ³	350,000
Geotextile, 43,900 yd ³ @ \$9.00/yd ³	<u>395,000</u>
TOTAL, Temporary Cell Cover	\$745,000

Final Cell Cover^o

Clay, 21,100 yd ³ @ \$6.99/yd ³ (fn p)	\$147,000
Sand/gravel, 14,600 yd ³ @ \$10.04/yd ³	147,000
Low-permeability soil, 14,600 yd ³ @ \$12.44/yd ³	182,000
Intrusion barrier, 29,300 yd ³ @ \$21/yd ³	615,000
Geotextile (3 layers), 131,700 yd ² @ \$9.00/yd ²	1,185,000
Topsoli, 29,300 yd ³ @ \$13.11/yd ³	<u>384,000</u>
TOTAL, Final Cell Cover	\$2,660,000

Site RestorationFactory SiteBackfill

Off-site, 149,200 yd ³ @ \$10.04/yd ³	\$1,500,000
On-site, 8,600 yd ³ @ 5.09/yd ³	<u>43,800</u>
	\$1,540,000
Topsoli, 25,200 yd ³ @ \$13.11/yd ³	330,000
Seed/mulch, 38,700 yd ² @ \$0.32/yd ²	<u>12,400^q</u>
TOTAL, Factory Site	\$1,880,000

Intermediate Site

Topsoli, 7,500 yd ³ @ \$13.11/yd ³	\$98,300
Seed/mulch, 38,700 yd ² @ \$0.32/yd ²	<u>12,400^q</u>
TOTAL, Intermediate Site	\$111,000

Disposal Site

Seed/mulch, 132,000 yd ² @ 0.32/yd ²	<u>42,200^q</u>
TOTAL, Site Restoration	\$2,040,000

Table F.1. Continued

<u>Other</u>	
Water collection, treatment, and disposal	-- ^r
TOTAL	\$14,200,000
General contractor's fee @ 10%	<u>\$1,420,000</u>
TOTAL, Action Period	\$15,600,000

^a Sources for unit costs: Means Co. (1984, 1986), U.S. Environmental Protection Agency (1982), Tri-State Motor Transit Co. (1986), and Schroff (1986). Volumes obtained from Table 2.2. Costs given to three significant figures.

^b Cost is for roads 10 yd wide with 8 in. of gravel fill.

^c Includes building demolition, construction of lighting, communication facilities as necessary, railroad crossing, and so forth. Sufficient data are not available to estimate the cost of these items.

^d Unit price is for polyvinylchloride pipe and includes \$0.93/ft for laying and trenching.

^e Unit price is for epoxy pipe reinforced with fiberglass.

^f Unit price is for one layer of geotextile. Quoted 1980 price range of \$1.50 to \$2.00/ft² is for two-layer geotextile backing (U.S. Environ. Prot. Agency 1982); the lower value was divided by two and then converted to a 1986 price by multiplying by a cost index factor of 1.33 (Means Co. 1986).

^g The off-site borrow costs for clay were assumed to be the same as for select fill.

^h Includes a 1-mile round-trip haul in 12-yd³ dump trucks. It was assumed the excavated soils were mainly E stratum sandy/gravelly soils.

ⁱ Includes a 0.5-mile round-trip haul.

^j Unit prices include a 0.25-mile round-trip haul.

^k Price includes \$20.65/yd³ for stabilization and neutralization by mixing, into each 1-ft deep layer, 40 kg lime per 1,000 kg tailings and then compacting the mixture (Means Co. 1986; Kerr-McGee 1986--Vol. VII).

^l Assumes that steel sheet 15 ft deep will be used for groundwater isolation and that the sheet used for one pond is not reusable for another pond. A common sheet between one side of ponds 4 and 5 is assumed. An overlap factor of 1.6 to allow for proper interlocking of the sheets (U.S. Environ. Prot. Agency 1982) and a 1980 to 1986 cost index multiplier of 1.33 (Means Co. 1986) were used.

^m Contaminated soils from the residential areas and the sanitary treatment plant are assumed to have been moved to the West Chicago site (Stauter 1986).

ⁿ The temporary cell cover is described in Kerr-McGee (1986--Vol. IX).

^o Volumes of the cover components are given in Kerr-McGee (1986--Vol. IV).

^p The cost includes excavation, stockpiling, backfilling, and recompacting the top 1.5 ft of the temporary cell cover. The bottom 0.5 ft of clay and geotextile of the temporary cell cover are left in place (Kerr-McGee 1986--Vol. IX).

^q It is assumed that the whole area is seeded with a utility grass mixture, mulched, and fertilized.

^r Sufficient data are not available to estimate the cost of these items.

The work force requirements for implementation of the Proposed Action were estimated as follows. The analysis of unit costs for various activities was based on the unit cost breakdown given by Means Company (1986) for material, labor, and equipment. According to this analysis, labor costs would be about 40% of the total cost, or \$6,200,000 (40% of \$15,600,000). Using an average cost for a skilled worker of \$29.90/hour, including overhead and profit (Means Co. 1986), the annual average cost during the action period would be \$60,000/year (assuming 2,000 hours/year of work) or 104 person-years (1 person-year is equivalent to 2,000 person-hours).

F.2 ALTERNATIVE A - DEEP-TRENCH DISPOSAL AT AN ACTIVE SURFACE COAL MINE

Details of the cost estimates for implementation of Alternative A, disposal at an active surface coal mine, are given in Table F.2. Many of the activities and unit costs are the same as for the Proposed Action. Other details are given in extensive footnotes to the table. A main item of expense in this alternative is the \$19,000,000 cost for bins (packages) needed to ship all the wastes that would be classified as low-specific-activity (LSA) radioactive wastes by the U.S. Department of Transportation. These wastes are the ore tailings, sludge pile material, pond 1 sediments, and materials listed in Table 5.13 of the main text. Bins would be needed because these wastes must be shipped in strong, tight containers (49 CFR Part 173). The bin cost figure given here assumes that the bins would be buried without being opened. If the bins could be reused, a significant reduction in cost might be possible.

Truck transport costs are also considerable, about \$22,000,000. These are based on the round-trip distance and rates for dedicated truck shipments of low-level radioactive waste (Tri-State Motor Transit Co. 1986).

These costs are offset somewhat by the small cost of cell preparation because the pit at the coal mine site has already been dug by the coal company. Cell cover costs would be more expensive for Alternative A than for the Proposed Action because more than twice the amount of material would be needed for the cover and it was assumed that all of the material would be purchased and hauled from a site 5 miles away. If cover materials were available on-site or could be obtained for a special rate from the coal company, significant cost savings would be possible.

Sufficient data are not available for several items for Alternative A, including activities such as water treatment and disposal, construction and use of truck washdown and decontamination facilities, radiological monitoring, and decommissioning of equipment and facilities. In order to minimize the amount of material that must be binned, additional funds must be expended for monitoring personnel to determine which truckloads must be binned and which can be shipped in bulk.

Table F.2. Details of Cost Estimates for Implementing Alternative A^a

<u>Site Preparation</u>	
Site purchase, 20 acres @ \$400/acre (fn b)	\$ 8,000
Road construction, 24,700 yd ² @ \$3.44/yd ² (fn c)	85,000
Security fence (chain link), 2470 yd @ \$46.05/yd (fn c)	114,000
Washdown facilities for trucks	-- ^d
Water treatment facilities	-- ^d
Parking lots, change house, etc.	-- ^d
TOTAL, Site Preparation	\$207,000
<u>Cell Preparation</u>	
Floor compaction, 18,200 yd ³ @ \$2.07/yd ³ (fn e)	\$ 37,600
Clay sidewall construction, 110,200 yd ³ @ \$3.78/yd ³ (fn f)	417,000
TOTAL, Cell Preparation	\$454,000
<u>Waste Excavation and Packaging</u>	
<u>Factory Site</u>	
Building rubble, 17,000 yd ³ @ \$0.98/yd ³ (fn g)	\$ 16,700
Contaminated soil	
LSA material (fn h)	
Excavate and load bins, 49,000 yd ³ (fn i)	
@ \$3.24/yd ³ (fn j)	159,000
Nonradioactive materials (fn k)	
Excavate and load trucks, 134,000 yd ³ (fn l)	
@ \$2.26/yd ³ (fn m)	303,000
TOTAL, Factory Site	\$479,000
<u>Intermediate Site</u>	
Soils, excavate and load, 7,500 yd ³ (fn n) @ \$2.26/yd ³ (fn m)	\$17,000
<u>Disposal Site</u>	
Ore tailings, 24,500 yd ³ (fns h,n) @ \$20/yd ³ (fn o)	\$490,000
Sludge pile, 5,000 yd ³ (fns h,n) @ \$1.96/yd ³ (fn o)	9,800
Ponds 2-5 sediments	
Isolation from groundwater	\$748,000 ^p
Dewatering	-- ^d
Sediment excavation	
LSA materials (ponds 2 & 3) (fn h)	
Excavate and load bins, 8,000 yd ³ (fn i)	
@ \$4.37/yd ³ (fns q,r)	\$ 35,000
Nonradioactive materials (ponds 4 & 5) (fn k)	
Excavate and load trucks, 5,000 yd ³ (fn l)	
@ \$3.39/yd ³ (fns m,q)	\$ 17,000
Pond 1 sediments	
Isolation from groundwater	\$154,000 ^p
Dewatering	-- ^d
Excavate and load bins, 27,000 yd ³	
@ \$4.37 yd ³ (fns q,r)	\$118,000
Contaminated soils	
LSA material (fn h)	
Excavate and load bins, 5,800 yd ³ (fn i)	
@ \$3.24/yd ³ (fns j,r)	\$18,800
Nonradioactive	
Excavate and load trucks, 29,200 yd ³ (fn l)	
@ \$2.26/yd ³ (fn m)	\$66,000

Table F.2. Continued

<u>Waste Excavation and Packaging (Continued)</u>	
Neighborhood soils, 35,000 yd ³ @ \$2.26/yd ³ (fn m)	\$79,000
Sanitary Treatment Plant soils, 11,800 yd ³ @ \$2.26/yd ³ (fn m)	<u>27,000</u>
TOTAL, Disposal Site	\$1,760,000
TOTAL, Waste Excavation and Packaging	\$2,260,000
<u>Transportation</u>	
Bins, 44,700 @ \$435/bin (fn s)	\$19,400,000
Truck trips	
Flatbed trucks, 7,450 @ \$935/trip (fn t)	6,970,000
Dump trucks, 16,100 @ \$935/trip (fn t)	<u>15,100,000</u>
TOTAL, Transportation	\$41,500,000
<u>Waste Placement</u>	
Binned waste, 44,700 bins @ \$5.13/bin (fn u)	\$229,000
Bulk waste, 250,000 yd ³ @ \$3.78/yd ³ (fn v)	<u>945,000</u>
TOTAL, Waste Placement	\$1,170,000
<u>Cell Cover</u>	
Clay/till, 209,000 yd ³ @ \$12.44/yd ³ (fn w)	\$2,600,000
Topsoli 54,400 yd ³ @ \$13.11/yd ³ (fn w)	<u>713,000</u>
TOTAL, Cell Cover	\$3,310,000
<u>Site Restoration</u>	
Disposal Site	
Seed/mulch, 96,800 yd ² @ \$0.32/yd ²	\$ 31,000
West Chicago Site	
Factory Site	\$1,840,000 ^p
Intermediate Site	111,000 ^p
Disposal Site	
Sand/gravel/clay backfill, 53,000 yd ³ @ 6.30/yd ³ (fn x)	\$334,000
Topsoli backfill, 88,000 yd ³ @ \$8.98/yd ³ (fn y)	791,000
Seed/mulch, 132,000 yd ² @ \$0.32/yd ²	<u>42,200</u>
TOTAL, Disposal Site	<u>\$1,170,000</u>
TOTAL, Site Restoration	\$3,150,000
TOTAL	\$52,100,000
General Contractor's Fee @ 10%	<u>5,200,000</u>
TOTAL, Action Period	\$57,300,000

Table F.2. Continued

- ^a Source of most unit costs: Means Co. (1986). Values rounded to three significant figures.
- ^b Source: Schroff (1986).
- ^c Costs refer to a site perimeter chain link fence and gravel road 10 yd wide with 8 in. of gravel around the site perimeter.
- ^d Sufficient data are not available for cost estimation.
- ^e Two passes by a sheepsfoot roller with 4-in. lifts was assumed to be used for compaction.
- ^f Existing till piled at base of wall is used for sidewall. Excavation and spreading assumed to be done by a 105-HP dozer with a 330-ft haul.
- ^g Excavation is assumed to be done with a 1.5-yd³ front-end loader. Unit cost includes loading on dump trucks.
- ^h Material classified as low-specific-activity (LSA) radioactive material for transportation purposes by U.S. Department of Transportation (49 CFR Part 173).
- ⁱ Volume is taken from Table 5.12 as that for above-criterion material.
- ^j Unit cost includes excavation by 1.5-yd³ crawler backhoe and filling bins @ \$2.26/yd³ and loading bins on flatbed truck @ \$0.98/yd³.
- ^k Material classified as nonradioactive for transportation purposes by U.S. Department of Transportation (49 CFR Part 173).
- ^l Volume is taken from Table 5.12 as that for below-criterion material.
- ^m Unit cost includes excavation by 1.5-yd³ crawler backhoe and loading dump trucks.
- ⁿ Volume is taken from Table 2.2.
- ^o Unit cost includes excavating by 1.5-yd³ front-end loader, filling bins and loading bins on flatbed trucks. For ore tailings, cost of neutralization is included.
- ^p Same as for the Proposed Action (see Table F.1).
- ^q Includes 50% surcharge for excavating wet material (Means Co. 1986).
- ^r Includes \$0.98/yd³ for loading bins on flatbed truck.
- ^s Source: Ditch (1986).
- ^t Mileage rates supplied by Tri-State Motor Transit Co. (1986). Cost/trip is for transport by dedicated trucks.
- ^u Unit cost assumes each bin holds about 3 yd³ of waste and includes cost of unloading, 100-meter haul, and placement of bins in waste pile. This cost is assumed to be the same per cubic yard as backfilling with a 105-HP dozer with a 330-ft haul.
- ^v Unit cost includes unloading, a 330-ft haul, spreading, and compaction.
- ^w Unit costs include cost of buying material and a 5-mile haul from the buying site. If the material were available on-site, the unit cost would be reduced considerably. Volumes are obtained from the total waste volume (Table 2.2) and Appendix B, Figure B.5.
- ^x Unit cost assumes sufficient clay/sand/gravel is available on-site and assumes half clay and half sand/gravel will be used. Topsoil volume assumes a 2-ft thickness over disposal site (Kerr-McGee 1986--Vol. IX).
- ^y Cost is prorated cost of \$6.85/yd for 58,000 yd³ available on-site (Kerr-McGee 1986--Vol. IX) and the remaining 30,000 yd³ purchased off-site, 5 miles distant, at \$13.11/yd³.

Work force estimates for Alternative A were obtained by assuming, as for the Proposed Action, that the labor cost would be 40% of the total cost (exclusive of transportation). Use of the cost estimates in Table F.2 results in a labor cost of \$6,400,000, or 106 person-years of work at \$60,000/year (see Section F.1) for all action period activities except transportation. The work force requirements for transportation were estimated based on a one-way trip distance of 180 miles; for this distance, one round trip can be made in about 10 hours (including about 2 hours per round trip for loading, unloading, washing the truck, etc.). At 2,000 hours per person-year and one driver per truck (Rutenkroger 1986), 200 truck trips per driver-year -- or a total of 118 driver-years (= 23,500 trips/200 trips per driver-year) -- would be required. The total work force requirement for Alternative A would be 224 person-years for the action period.

F.3 ALTERNATIVE B - DISPOSAL AT A RECLAIMED SURFACE COAL MINE

Costs for most activities associated with Alternative B are about the same as those for Alternative A, and a separate cost breakdown for Alternative B has not been prepared. Some cost items that differ for Alternative B are land acquisition, \$16,000 (more expensive land cost per acre--Maloof 1986); and cost per dedicated truck trip, \$909/trip (compared with \$935/trip in Alternative A) (Rutenkroger 1986).

The activity unique to Alternative B is the pumping out of the lake in the abandoned ravine where the wastes would be buried. Rental of a submersible pump with a 4-in.-diameter outlet that pumps at a rate of 560 gpm, plus purchase and laying of 0.5 mile of 6-in.-diameter plastic pipe on the surface to a convenient drainage point, would cost about \$8,000 for the pipe and about \$710 per month for the pump, including fuel and maintenance. Such a pump operating continuously would remove about 74 acre-ft of water in one month. Because the lake contains about 350 acre-ft of water, 5 months of continuous pumping would be sufficient to drain the lake at a total cost of about \$15,000. After the lake was pumped dry, the bottom of the lake would have to be allowed to dry before it could be graded and compacted. The cost for grading and compacting would be similar to that for Alternative A.

A potential additional cost would be for treatment of the lake water to remove contaminants before the water was released. Data are not available on the concentrations of contaminants in the lake. However these concentrations should be similar to those of other nearby lakes in abandoned strip mines and streams that are fed by such lakes.

The activities and estimated costs of activities for Alternative B, \$56,500,000, are about the same as those for Alternative A. Also, the

transportation distance of 174 miles and the work force requirement for the action period of 223 person-years are about the same as for Alternative A.

F.4 ALTERNATIVE C - DISPOSAL AT AN UNDERGROUND COAL MINE

Details of the cost estimates for implementation of Alternative C, disposal in panels of an underground coal mine, are given in Table F.3. Some of the activities and unit costs are the same as for Alternative A. Other details are given in the footnotes to Table F.3.

The unique feature of Alternative C would be underground burial in rooms or panels that have already been excavated. Sufficient data are not available to estimate the cost of this operation. Unknown factors include such things as the amount of work needed to ensure that the roof and pillars of the room would be secure against collapse during waste emplacement and the possibility that the wastes shipped in bulk would have to be stored underground in bins. The latter factor is based on the possibility that bulk underground storage might result in so much dust and radon accumulation in the confined underground areas during waste emplacement that the bulk, unbinned burial procedure could be hazardous to the workers involved. In addition, the wastes must be placed in containers for the descent by hoist to the panel.

Another problem in estimating costs for Alternative C is the possibility that some equipment and facilities could be purchased from the current mine owners at the time the disposal site was obtained. The site purchase cost of \$456,000 (Table F.3) is for the land only and does not include any improvements or equipment that might be present at the disposal site, such as water and sewer lines, a sewage treatment plant, water storage tanks, mine ventilation and degassing systems, shaft elevators and hoists, heavy equipment (bulldozers, scrapers, front-end loaders, etc.), and buildings.

The cost of these items, appropriately depreciated in annual increments, is an important part of waste emplacement costs. Because these costs as well as many other details of the waste emplacement operation are not known, it was assumed that the cost per cubic yard of moving the waste down into the mine and placing it in the panel would be about twice the unit cost (Table F.1) for above-grade burial of the waste at the West Chicago site, or about \$10/yd³. This results in a total cost for placement of bulk waste for Alternative C of \$2,500,000. If binning were required, the cost would be higher; however, because the only purpose of the bins would be to contain the wastes during descent into the mine shaft and during placement in the panel, the bins could be less sturdy and cheaper than those used for shipping the LSA waste.

The LSA waste would remain in the shipping bins for permanent underground burial in the panel (unless the bins could be reused). The unit cost for

Table F.3. Details of Cost Estimates for Implementing Alternative C^a

<u>Site Preparation</u>	
Site purchase, 190 acres @ \$2400/acre (fn b)	\$456,000
Road construction, 38,400 yd ² @ \$3.44/yd ² (fn c)	132,000
Security fence, 3840 yd @ \$46.05/ya (fn c)	177,000
Washdown facilities for trucks	-- ^d
Water treatment facilities	-- ^d
Parking lots, etc.	-- ^d
TOTAL, Site Preparation	\$765,000
<u>Panel Preparation</u>	
Roof and pillar repair	-- ^d
Shaft repair	-- ^d
Other (fn e)	-- ^d
TOTAL, Panel Preparation	-- ^d
<u>Waste Excavation and Packaging</u>	\$2,260,000 ^f
<u>Transportation</u>	
Bins	\$19,400,000 ^f
Truck trips	
Flatbed trucks, 7,450 @ \$954/trip (fn g)	7,110,000
Dump trucks, 16,100 @ \$954/trip (fn g)	15,400,000
TOTAL, Transportation	\$41,900,000
<u>Waste Placement</u>	
Binned waste, 44,700 bins @ \$10/bin (fn h)	\$ 447,000
Bulk waste, 250,000 yd ³ @ \$10/yd ³ (fn h)	2,500,000
TOTAL, Waste Placement	\$2,950,000
<u>Site Restoration</u>	\$3,120,000 ⁱ
TOTAL	\$51,000,000
General Contractors Fee @ 10%	5,100,000
TOTAL, Action Period	\$56,100,000

^a Source for most unit costs is Means Company (1986). Dollar values are rounded to three significant figures.

^b Source: Snyder (1986).

^c Costs refer to a road 10 yd wide with 8 in. of gravel and a chain link fence along the site perimeter.

^d Sufficient data are not available for cost estimation.

^e Includes such items as haulage systems, water pumps, floor repair, ventilation system, etc..

^f Values are the same as for Alternative A, see Table F.2.

^g Mileage rates supplied by Tri-State Motor Transit Co. (1986). Cost per trip is for transport by dedicated trucks.

^h Unit costs are estimated because sufficient data are not available. See text for details.

ⁱ Value is the sum of costs given in Table F.2 for the West Chicago site only. Costs for the disposal site are expected to be small.

placing the LSA waste bins in the underground panel was also assumed to be about twice that for placement of binned wastes in Alternative A, or about \$10/bin. This results in a total LSA waste emplacement cost of about \$450,000 for Alternative C. The total waste emplacement cost for Alternative C is the sum of the bulk and LSA costs, or about \$2,900,000. The corresponding cost for Alternative A is lower, about \$1,200,000 (Table F.2).

Offsetting this cost is the fact that for Alternative C, no cover, side-walls, or floor would have to be constructed because the panel has already been excavated. The \$3,800,000 cost of these activities for Alternative A would be avoided. The net cell construction and waste emplacement cost under Alternative C would be cheaper than that for Alternative A by \$2,100,000 ($\$3,800,000 + \$1,200,000 - \$2,900,000$). However, this saving would be reduced or even eliminated if extensive underground repair work and water pumping were necessary or if the bulk wastes had to be binned.

Costs for site preparation activities for Alternative C should be similar to those for Alternative A because the same activities would be required (see Table F.2 for a list of these activities). Site restoration costs for Alternative C would be smaller than for Alternative A or B because minimal seeding and mulching would be required at the disposal site. Costs for other activities associated with Alternative C, such as those at the West Chicago site, would be the same as for Alternative A (Table F.2). Also, for each activity, the level of effort or cost should be similar for Alternatives A and C.

The total cost for Alternative C for all action period activities except transportation would be \$14,000,000; this is about \$2,000,000 lower (see above) than the cost for Alternative A, \$16,000,000 (Table F.2). Assuming that 40% is labor cost at a unit cost of \$60,000/year (Section F.1), 95 person-years would be required for Alternative C. The transportation distance of 168 miles is 25 miles less per round trip than the distance for Alternative A. Assuming 9 hours per round-trip, a total of 106 driver-years would be required for transportation (see Section F.2 for description of calculations). The total work force requirement for Alternative C would be 201 person-years during the action period.

F.5 ALTERNATIVE D - PARTIAL BURIAL ON A FARMLAND SITE

The activities under Alternative D are essentially a combination of those for the Proposed Action and Alternative A. Cost details are given in Table F.4. Cell construction would be essentially the same as that for the Proposed Action except that the cover in Alternative D would cost more because it would cover a larger area than the cover for the Proposed Action. Also, it was assumed for Alternative D that the topsoil, low-permeability soil, and clay would be available on-site and would not have to be purchased. As in

Table F.4. Details of Cost Estimates for Implementing Alternative D^a

<u>Site Preparation</u>	
Site purchase, 47 acres @ \$1500/acre (fn b)	\$ 71,000
Access road, 5,280 ft @ \$60/ft (fn c)	317,000
Perimeter gravel road, 19,100 yd ² @ \$3.44/yd ²	65,700 ^d
Security fence, 1,910 yd @ \$46.05/yd	88,000 ^d
Washdown facilities for trucks	-- ^e
Water treatment facilities	-- ^e
Temporary buildings, parking lots, etc.	-- ^e
TOTAL, Site Preparation	\$542,000
<u>Cell Floor</u>	
Excavation, 180,000 yd ³ @ \$2.54/yd ³ (fn f)	\$457,000
Floor compaction, 150,000 yd ³ @ 1.04/yd ³ (fn f)	\$156,000
Leachate monitoring system	
Sand/gravel drain, 45,400 yd ³ @ 10.04/yd ³ (fn g)	\$456,000
4" drain pipe, 11,100 ft @ \$3.37/ft (fn h)	37,400
6" manifold pipe, 2,300 ft @ \$4.08/ft (fn h)	9,400
6" riser, 460 ft @ \$28/ft (fn h)	12,900
	<u>\$ 516,000</u>
Geotextile, 137,000 yd ² @ \$9.00/yd ² (fn h)	1,230,000
TOTAL, Cell Floor	\$2,350,000
Waste Excavation, Packaging	\$2,260,000 ⁱ
<u>Transportation</u>	
Bins	\$19,400,000 ⁱ
Truck trips	
Flatbed trucks, 7,450 @ \$581/trip	4,330,000
Dump trucks, 16,100 @ \$581/trip	<u>9,350,000</u>
TOTAL, Transportation	\$33,100,000
Waste Placement	1,170,000 ⁱ
<u>Cell Cover</u>	
Clay, 104,100 yd ³ @ \$4.90/yd ³ (fn j)	\$ 510,000
Sand/gravel, 49,900 yd ³ @ \$10.04/yd ³ (fn h)	500,000
Low-permeability soil, 49,100 yd ³ @ \$4.90/yd ³ (fn j)	241,000
Intrusion barrier, 97,200 yd ³ @ \$21/yd ³ (fn h)	2,040,000
Geotextile (3 layers), 444,000 yd ² @ \$9/yd ² (fn h)	4,000,000
Topsoil, 93,900 yd ³ @ \$4.24/yd ³ (fn j)	<u>398,000</u>
TOTAL, Cell Cover	\$7,690,000
<u>Site Restoration</u>	
West Chicago site	\$3,120,000 ^k
Disposal site	
Seed/mulch, 235,000 yd ² @ \$0.32/yd ²	<u>75,000</u>
TOTAL, Site Restoration	\$3,200,000
TOTAL	\$50,300,000
General Contractor's Fee @ 10%	<u>5,030,000</u>
TOTAL, Action Period	\$55,300,000

Table F.4. Continued

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- ^a Source for most unit costs: Means Company (1986).
 - ^b Source: Hamilton (1986).
 - ^c Unit cost is an average value for two-lane asphalt-paved roads (Means Co. 1986).
 - ^d Costs refer to a chain link fence and gravel road 10 yd wide with 8 in. of gravel along the site perimeter.
 - ^e Sufficient data are not available for cost estimation.
 - ^f Unit cost assumes excavation by a 1.5-yd³ front-end loader and a 0.25-mile (one-way) haul in 12-yd³ trucks. Compaction of the floor to a depth of 3.3 ft by a sheepfoot roller with 8-in. lifts in two passes are assumed.
 - ^g Includes purchase and a 5-mile haul.
 - ^h See Table F.1.
 - ⁱ See Table F.2.
 - ^j Unit costs are based on assumption that the material is available on-site.
 - ^k See Table F.3.

Alternative A, the wastes must be binned and transported and the disposal site purchased for Alternative D. Transport costs would be less than for Alternative A because the site is closer (81 miles) to the West Chicago site. As for the other alternatives, there are activities for which sufficient data are not available for cost estimation; some of these are indicated in Table F.2.

The person-year requirements for Alternative D were calculated in the same manner as for Alternative A (Section F.2). Based on the costs in Table F.4, 149 person-years would be required for all activities except transportation. Because of the shorter trip distance (81 miles), one round trip would require about 6 hours of driver time, or about 330 round trips per driver-year (one driver-year equals 2,000 driver-hours); 23,500 round trips would require a total of 71 driver-years, with one driver per truck (Section F.2). The total work force requirement for Alternative D would be 220 person-years for the action period.

F.6. COSTS OF MAINTENANCE, MONITORING, AND SURVEILLANCE

The costs of maintenance, monitoring, and surveillance (MMS) activities for the Proposed Action and Alternatives A-D are quite uncertain because of the lack of long-term experience with the types of containment proposed for the Kerr-McGee wastes. For a waste-disposal facility at Weldon Spring, Missouri -- which is similar to the one considered here for the Proposed Action -- it has been estimated that the equivalent of two full-time persons per year would be required for the first 5 years following site closure (Bechtel Natl. 1984). For a program similar to that proposed by Kerr-McGee, estimated costs in 1984 dollars are \$20,000/year for environmental monitoring, \$3,500/year for fuel, and \$15,000/year for utilities (Bechtel Natl. 1984).

Conversion of these costs to 1986 dollars by use of a cost-inflation factor of 1.024 gives a total of \$39,400/year for environmental monitoring, fuel, and utilities. The average cost for skilled workers, including the subcontractor's overhead and profit, is \$60,000/year in 1986 dollars (Means Co. 1986). Multiplying by two and adding the other costs gives a total of about \$160,000/year for MMS activities for the first 5 years following site closure. This figure is close to that given by EG&G (1983) for extended care following closure of an intermediate-sized waste-disposal facility for low-level radioactive wastes that received over its lifetime a total waste volume that is close to that for the Kerr-McGee wastes. EG&G's cost estimate in 1981 dollars corrected to 1986 dollars is \$157,000/year.

The \$160,000/year cost in 1986 dollars was assumed here to apply to the Proposed Action for the first 5 years following site closure. During the next 5 years, the cost for MMS activities is assumed to drop by 50% to \$80,000/year. This reduction is based on the fact that most monitoring activities would be carried out half as often during the second 5-year period (see Chapter 7 and Kerr-McGee 1986--Vol XI). These MMS costs and those for the other alternatives represent current (1986) costs and are not discounted to the time the activity begins.

During the balance of the 1,000-year period, the frequency of monitoring activities would drop by another factor of two. Some other activities would drop by a smaller factor and for still other activities the level would drop by a larger factor (see Chapter 7 and Kerr-McGee 1986--Vol XI). Here the factor of two is assumed to apply to the sum of costs for all activities. As a result, the annual cost for MMS activities during this period for the Proposed Action would drop by another factor of two to \$40,000/year (in 1986 dollars). This value is a rough estimate because costs for these activities over such a long time period are not known.

For Alternatives A and B, the wastes would be buried below grade, and MMS activities for surface water runoff monitoring and cap repair should be less than for the Proposed Action. However, air and groundwater monitoring activities are expected to be similar. Consequently, costs for MMS activities were assumed to be about half those for the Proposed Action, or \$80,000/year for the first 5 years, \$40,000/year for the next 5 years, and \$20,000/year for the remainder of the 1,000-year period. For Alternative C, only groundwater monitoring and occasional air monitoring would be needed because the wastes would be buried deep underground. Thus, MMS activities were assumed to cost 25% of those for the Proposed Action, or \$40,000/year for the first 5 years, \$20,000/year for the next 5 years, and \$10,000/year thereafter. For Alternative D, the wastes would be buried in open farmland, and surface runoff and erosion rates should be similar to those associated with the Proposed

Action. On this basis, the costs for MMS activities were assumed to be the same as those for the Proposed Action, or \$160,000/year for the first 5 years, \$80,000/year for the next 5 years, and \$40,000/year thereafter.

The costs for MMS activities are summarized in Table F.5. The costs are presented in three ways as (1) an annual cost, (2) a total cost for the 1,000-year period, and (3) a sinking fund sufficient to make payments for the first 5 years at the higher annual rate, the next 5 years at the lower rate, and 990 years thereafter at the final rate. It is assumed that the sinking fund is set up at the beginning of the 7-year action period. Also, a cost-inflation rate of 5% per year is assumed for the action period and for the first two 5-year periods of the 1,000-year period. A real interest rate of 1% per year is assumed during the 1,000-year period. (It is unnecessary to assume an inflation rate for the 990-year balance of the long-term period because the sinking fund is independent of the inflation rate for this period.) All costs are given in 1986 dollars.

Table F.5. Summary of Costs of Maintenance, Monitoring, and Surveillance Activities for the Various Alternatives

	Cost (thousands of 1986 dollars)				
	Proposed Action	Alt. A	Alt. B	Alt. C	Alt. D
Annual Cost					
First 5 years	160	80	80	40	160
Next 5 years	80	40	40	20	80
Next 990 years	40	20	20	10	40
Total Cost	41,000	20,000	20,000	10,000	41,000
Sinking Fund^a	4,390	2,200	2,200	1,100	4,390

^a Calculated assuming a 5% inflation rate for the first 10 years and a 1% real annual interest rate for 1,000 years.

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APPENDIX G. ENGLISH/METRIC - METRIC/ENGLISH EQUIVALENTS

Table G.1. English/Metric - Metric/English Equivalents

Multiply	By	To obtain
acres	0.4047	hectares (ha)
cubic feet (ft ³)	0.02832	cubic meters (m ³)
cubic yards (yd ³)	0.7646	cubic meters (m ³)
degrees Fahrenheit (°F) - 32	0.5555	degrees Celsius (°C)
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
gallons (gal)	0.003785	cubic meters (m ³)
inches (in.)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
square feet (ft ²)	0.09290	square meters (m ²)
square yards (yd ²)	0.8361	square meters (m ²)
square miles (mi ²)	2.590	square kilometers (km ²)
tons, short (t)	907.2	kilograms (kg)
tons, short (t)	0.9072	tons, metric (MT)

centimeters (cm)	0.3937	inches (in.)
cubic meters (m ³)	35.31	cubic feet (ft ³)
cubic meters (m ³)	1.308	cubic yards (yd ³)
cubic meters (m ³)	264.2	gallons (gal)
degrees Celsius (°C) + 17.78	1.8	degrees Fahrenheit (°F)
hectares (ha)	2.471	acres
kilograms (kg)	2.205	pounds (lb)
kilograms (kg)	0.001102	tons, short (t)
kilometers (km)	0.6214	miles (mi)
liters (L)	0.2642	gallons (gal)
meters (m)	3.281	feet (ft)
square kilometers (km ²)	0.3861	square miles (mi ²)
square meters (m ²)	10.76	square feet (ft ²)
square meters (m ²)	1.196	square yards (yd ²)
tons, metric (MT)	1.102	tons, short (t)

NRC FORM 338 (2-84) NRCM 1102, 3301, 3302 BIBLIOGRAPHIC DATA SHEET SEE INSTRUCTIONS ON THE REVERSE		U.S. NUCLEAR REGULATORY COMMISSION		1. REPORT NUMBER (Assigned by TIDC, add Vol. No., if any) NUREG-0904 Supplement No. 1	
2. TITLE AND SUBTITLE Draft Supplement to the Final Environmental Statement Related to the Decommissioning of the Rare Earths Facility, West Chicago, Illinois Docket No. 40-2061				3. LEAVE BLANK	
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12. SUPPLEMENTARY NOTES Pertains to Docket 40-2061 and ASLBP No. 83-495-01-ML				9. FIN OR GRANT NUMBER	
13. ABSTRACT (300 words or less) This Draft Supplement to the Final Environmental Statement is issued by the U.S. Nuclear Regulatory Commission in response to the Atomic Safety and Licensing Board's ruling that the staff must supplement the Final Environmental Statement in order to evaluate the impacts of permanent disposal of the Kerr-McGee Rare Earths Facility wastes located at West Chicago, Illinois. The statement considers the Kerr-McGee preferred plan and various alternatives to the plan. The action proposed by the Commission is the renewal of the Kerr-McGee license to allow disposal of wastes onsite and for possession of the wastes under license for an indeterminate time. The license could be terminated at a later date if certain specified requirements were met.				11a. TYPE OF REPORT Draft Supplement to the Environmental Statement b. PERIOD COVERED (Inclusive dates)	
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